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MATHÉMATIQUES

SUR LES CONGRUENCES DE SYSTÈMES D'ÉLÉMENTS D'UN GROUPE

Par P. SČYPANOFF

(Présenté par O. J. Schmidt, de l'Académie, le 10. VIII. 1939)

Le but de la présente Note est d'introduire la notion de congruence pour les systèmes d'éléments $\mathfrak{S}$ et $\mathfrak{S}'$ appartenant à un certain groupe $\mathfrak{G}$.

Dans le § 1 nous donnons la définition fondamentale et nous établissons certaines propriétés des congruences de systèmes par rapport à un module $\mathfrak{H}$. Les résultats obtenus permettent (§ 2) de formuler simplement et d'établir quelques théorèmes sur l'existence de sous-groupes invariants dans les groupes finis et infinis. Ces théorèmes contiennent comme cas particulier des propositions précédemment établies par A. Koulakoff et A. Ditzman [1].

§ 1. Soit $\mathfrak{G}$ un certain groupe, $\mathfrak{H}$ son sous-groupe, $\mathfrak{S}$ et $\mathfrak{S}'$ des systèmes d'éléments appartenant au groupe $\mathfrak{G}$. Nous dirons que les systèmes $\mathfrak{S}$ et $\mathfrak{S}'$ sont congrus par rapport au module $\mathfrak{H}$, si les deux conditions suivantes sont vérifiées: 1) si chaque élément S du système $\mathfrak{S}$ peut être présenté dans la forme HS', où H est un certain élément du groupe $\mathfrak{H}$ et S' est un certain élément du système $\mathfrak{S}'$ et 2) si chaque élément S_1' du système $\mathfrak{S}'$ peut être présenté dans la forme H_1S_1, où H_1 est un certain élément du groupe $\mathfrak{H}$ et S_1—un certain élément du système $\mathfrak{S}$.

La congruence des systèmes $\mathfrak{S}$ et $\mathfrak{S}'$ par rapport au module $\mathfrak{H}$ sera désignée symboliquement par

$$\mathfrak{S} \equiv \mathfrak{S}' \pmod{\mathfrak{H}}.$$

On déduit immédiatement de la définition posée les propriétés suivantes des congruences:

I. *Quel que soit le module de la congruence* $\mathfrak{H}$, *on a* $\mathfrak{S} \equiv \mathfrak{S} \pmod{\mathfrak{H}}$.

II. Il suit de $\mathfrak{S} \equiv \mathfrak{S}' \pmod{\mathfrak{H}}$ que l'on a $\mathfrak{S}' \equiv \mathfrak{S} \pmod{\mathfrak{H}}$.

III. Si $\mathfrak{S} \equiv \mathfrak{S}_1 \pmod{\mathfrak{H}}$ et $\mathfrak{S}_1 \equiv \mathfrak{S}_2 \pmod{\mathfrak{H}}$, on a $\mathfrak{S} \equiv \mathfrak{S}_2 \pmod{\mathfrak{H}}$.

En effet, chaque élément S du système $\mathfrak{S}$ peut être présenté dans la forme $S = HS_1$, où H est un certain élément du groupe $\mathfrak{H}$ et S_1—un certain élément du système $\mathfrak{S}_1$. D'autre part, $S_1 = H_1S_2$, où H_1 est un certain élément du groupe $\mathfrak{H}$ et S_2 est un certain élément de $\mathfrak{S}_2$. On a donc $S = HH_1S_2 = H'S_2$, où $H' = HH_1$. En vertu de la propriété II on peut écrire les congruences (I) et (II) dans la forme

$$\mathfrak{S}_2 \equiv \mathfrak{S}_1 \pmod{\mathfrak{H}}$$

et

$$\mathfrak{S}_1 \equiv \mathfrak{S} \pmod{\mathfrak{H}}.$$

On voit d'une manière analogue que chaque élément S_2 du système $\mathfrak{S}_2$ peut être présenté dans la forme $H''S'$, où H'' est un élément du groupe $\mathfrak{H}$.

On a ainsi $\mathfrak{S} \equiv \mathfrak{S}_2 \pmod{\mathfrak{H}}$.

IV. Si $\mathfrak{H}_1$ et $\mathfrak{H}_2$ sont des sous-groupes du groupe $\mathfrak{G}$ et si $\mathfrak{H}_2 \supseteq \mathfrak{H}_1$, il suit de $\mathfrak{S} \equiv \mathfrak{S}' \pmod{\mathfrak{H}_1}$ que l'on a

$$\mathfrak{S} \equiv \mathfrak{S}' \pmod{\mathfrak{H}_2}.$$

En particulier si

$$\begin{aligned} &\mathfrak{S} \equiv \mathfrak{S}' \pmod{\mathfrak{H}_1} \\ &\mathfrak{S} \equiv \mathfrak{S}' \pmod{\mathfrak{H}_2} \\ &\cdots\cdots\cdots \\ &\mathfrak{S} \equiv \mathfrak{S}' \pmod{\mathfrak{H}_n} \end{aligned}$$

où $\mathfrak{H}_1, \mathfrak{H}_2, \ldots, \mathfrak{H}_n$ sont des sous-groupes du groupe $\mathfrak{G}$, on a $\mathfrak{S} \equiv \mathfrak{S}' \pmod{\mathfrak{H}}$, où $\mathfrak{H}$ est le plus petit multiple des groupes $\mathfrak{H}_1, \mathfrak{H}_2, \ldots, \mathfrak{H}_n$.

V. Convenons de désigner par $\mathfrak{A} + \mathfrak{B} + \ldots + \mathfrak{F}$ l'ensemble des éléments appartenant à l'un au moins des systèmes $\mathfrak{A}, \mathfrak{B}, \ldots, \mathfrak{F}$. Alors si

$$\left.\begin{aligned} &\mathfrak{S}_1 \equiv \mathfrak{T}_1 \pmod{\mathfrak{H}} \\ &\mathfrak{S}_2 \equiv \mathfrak{T}_2 \pmod{\mathfrak{H}} \\ &\cdots\cdots\cdots \\ &\mathfrak{S}_n \equiv \mathfrak{T}_n \pmod{\mathfrak{H}} \end{aligned}\right\} \qquad (1)$$

on a $\mathfrak{S}_1 + \mathfrak{S}_2 + \ldots + \mathfrak{S}_n \equiv \mathfrak{T}_1 + \mathfrak{T}_2 + \ldots + \mathfrak{T}_n \pmod{\mathfrak{H}}$.

Remarquons que la propriété V reste vraie même dans le cas où il y a une infinité de congruences (I).

VI. *Soit $\mathfrak{A}$ un système arbitraire appartenant au groupe $\mathfrak{G}$ (ainsi que les systèmes $\mathfrak{S}$ et $\mathfrak{S}'$). Il suit alors de*

$$\mathfrak{S} \equiv \mathfrak{S}' \pmod{\mathfrak{H}}$$

que l'on a

$$\mathfrak{S}\mathfrak{A} \equiv \mathfrak{S}'\mathfrak{A} \pmod{\mathfrak{H}}.$$

VII. *Si le module $\mathfrak{H}$ de la congruence est un diviseur normal du groupe, il suit de*

$$\begin{aligned} &\mathfrak{S}_1 \equiv \mathfrak{T}_1 \pmod{\mathfrak{H}} \\ &\mathfrak{S}_2 \equiv \mathfrak{T}_2 \pmod{\mathfrak{H}} \end{aligned}$$

que l'on a

$$\mathfrak{S}_1\mathfrak{S}_2 \equiv \mathfrak{T}_1\mathfrak{T}_2 \pmod{\mathfrak{H}}.$$

En effet, chaque élément S_1 du système $\mathfrak{S}_1$ peut être présenté dans la forme $S_1 = H_1T_1$, (où H_1 est un certain élément de $\mathfrak{H}$, T_1 est un certain élément de $\mathfrak{T}_1$) et chaque élément S_2 du système $\mathfrak{S}_2$ peut être présenté dans la forme $S_2 = H_2T_2$ (où H_2 est un certain élément de $\mathfrak{H}$, T_2 est un certain élément de $\mathfrak{T}_2$).

On a évidemment

$$S_1S_2 = H_1T_1H_2T_2 = H_1T_1H_2T_1^{-1}T_1T_2 = HH'T_1T_2 = H''T_1T_2,$$

où H' et H'' sont des éléments du groupe $\mathfrak{H}$.

VIII. *Si le module de la congruence $\mathfrak{H}$ est un diviseur normal du groupe et $\mathfrak{T}$ est un système arbitraire d'éléments appartenant à $\mathfrak{G}$, il suit de*

$$\mathfrak{S} \equiv \mathfrak{S}' \pmod{\mathfrak{H}}$$

que l'on a

$$\mathfrak{T}\mathfrak{S} \equiv \mathfrak{T}\mathfrak{S}' \pmod{\mathfrak{H}}.$$

En effet, si $S = HS'$, on a

$$TS = THS' = THT^{-1}TS' = H'TS'$$

où S appartient à $\mathfrak{S}$, S' appartient à $\mathfrak{S}'$, H et H' sont des éléments de $\mathfrak{H}$ et T est un élément du système $\mathfrak{T}$.

§ 2. Démontrons d'abord un théorème auxiliaire qui sera utilisé dans la suite pour déduire des critères d'un groupe non-simple.

Théorème I. *Soit* $\mathfrak{G}$ *un groupe,* $\mathfrak{S}$*—un système d'éléments de* $\mathfrak{G}$, $\mathfrak{H}$*—un sous-groupe du groupe* $\mathfrak{G}$. *L'ensemble* $\mathfrak{F}$ *d'éléments* X *du groupe* $\mathfrak{G}$ *vérifiant la condition*

$$\mathfrak{S}X \equiv \mathfrak{S} \pmod{\mathfrak{H}} \tag{1}$$

est un groupe. Si $\mathfrak{H}\mathfrak{S}$ *ne coïncide pas avec* $\mathfrak{G}$, $\mathfrak{F}$ *ne coïncide pas avec* $\mathfrak{G}$.

Démonstration. Soient X_1 et X_2 des éléments du groupe $\mathfrak{G}$ vérifiant la condition (1), donc

$$\mathfrak{S}X_1 \equiv \mathfrak{S} \pmod{\mathfrak{H}} \tag{2}$$

$$\mathfrak{S}X_2 \equiv \mathfrak{S} \pmod{\mathfrak{H}}. \tag{3}$$

En vertu de la propriété VI du § 1 il suit de (2) que

$$\mathfrak{S}X_1X_2 \equiv \mathfrak{S}X_2 \pmod{\mathfrak{H}};$$

ensuite, en vertu de la propriété III on conclut

$$\mathfrak{S}X_1X_2 \equiv \mathfrak{S} \pmod{\mathfrak{H}}$$

donc l'élément X_1X_2 appartient aussi à l'ensemble $\mathfrak{F}$. L'unité appartient aussi à $\mathfrak{F}$ et il reste à démontrer que si

$$\mathfrak{S}X \equiv \mathfrak{S} \pmod{\mathfrak{H}} \tag{4}$$

on a

$$\mathfrak{S}X^{-1} \equiv \mathfrak{S} \pmod{\mathfrak{H}}. \tag{5}$$

Mais ceci est évident, car il résulte de (4) que

$$\mathfrak{S} \equiv \mathfrak{S}X^{-1} \pmod{\mathfrak{H}}$$

et cette congruence, en vertu de II, est équivalente à (5). Montrons maintenant que si $\mathfrak{H}\mathfrak{S}$ ne coïncide pas avec $\mathfrak{G}$, alors $\mathfrak{F}$ ne peut pas coïncider avec $\mathfrak{G}$. En effet, si $\mathfrak{F}$ coïncidait avec $\mathfrak{G}$, alors $\mathfrak{S}\mathfrak{F}$ coïnciderait avec $\mathfrak{G}$ et de $\mathfrak{H}\mathfrak{S} \supseteq \mathfrak{S}\mathfrak{F}$ on pourrait conclure que $\mathfrak{H}\mathfrak{S} = \mathfrak{G}$, ce qui contredit à l'hypothèse faite. En s'appuyant sur le théorème I nous démontrerons maintenant la proposition suivante.

Théorème II. *Soit* $\mathfrak{G}$ *un certain groupe,* $\mathfrak{H}$*—son sous-groupe,* $\mathfrak{A}$*—un complexe invariant d'éléments du groupe* $\mathfrak{G}$, $\mathfrak{S}$ *et* $\mathfrak{S}'$ *deux systèmes d'éléments de* $\mathfrak{G}$. *Si pour chaque élément* A *du complexe invariant* $\mathfrak{A}$ *on a*

$$\mathfrak{S}A \equiv \mathfrak{S}' \pmod{\mathfrak{H}} \quad \textit{et} \quad \mathfrak{H}\mathfrak{S} \subset \mathfrak{G},$$

le groupe $\mathfrak{G}$ *a un diviseur normal.*

Démonstration. Soient $A_1, A_2, A_3, \ldots$ les éléments formant le complexe invariant $\mathfrak{A}$. En vertu de la condition du théorème nous avons

$$\mathfrak{S}A_1 \equiv \mathfrak{S}' \pmod{\mathfrak{H}} \tag{6}$$

$$\mathfrak{S}A_2 \equiv \mathfrak{S}' \pmod{\mathfrak{H}} \tag{7}$$

. . . . . .

En vertu de la propriété V il en résulte

$$\mathfrak{S}\mathfrak{A} \equiv \mathfrak{S}' \pmod{\mathfrak{H}}.$$

En vertu de la propriété VI on a ensuite

$$\mathfrak{S}\mathfrak{A}\mathfrak{A}^{-1} = \mathfrak{S}'\mathfrak{A}^{-1} (\mathrm{mod}\ \mathfrak{H}) \qquad (8)$$

où $\mathfrak{A}^{-1}$ est le complexe invariant composé d'éléments inverses à ceux du complexe $\mathfrak{A}$.

D'autre part, il suit des égalités (6) et (7) que

$$\mathfrak{S} \equiv \mathfrak{S}' A_1^{-1} (\mathrm{mod}\ \mathfrak{H})$$

$$\mathfrak{S} \equiv \mathfrak{S}' A_2^{-1} (\mathrm{mod}\ \mathfrak{H})$$

. . . . . .

d'où

$$\mathfrak{S} \equiv \mathfrak{S}' \mathfrak{A}^{-1} (\mathrm{mod}\ \mathfrak{H})$$

ce qui en vertu de la propriété II est équivalent à la congruence

$$\mathfrak{S}'\mathfrak{A}^{-1} \equiv \mathfrak{S} (\mathrm{mod}\ \mathfrak{H}). \qquad (9)$$

En comparant (8) et (9) et en tenant compte de la propriété III, on conclut que

$$\mathfrak{S}\mathfrak{A}\mathfrak{A}^{-1} \equiv \mathfrak{S} (\mathrm{mod}\ \mathfrak{H}).$$

En vertu du théorème I le complexe invariant d'éléments de $\mathfrak{A}\mathfrak{A}^{-1}$ doit appartenir à un sous-groupe $\mathfrak{F}$ du groupe $\mathfrak{G}$, donc donner lieu à un diviseur normal du groupe $\mathfrak{G}$. En particulier, en posant $\mathfrak{H} = 1$ dans la condition du théorème II on obtient le résultat suivant.

Théorème III. *Soit $\mathfrak{G}$ un certain groupe, $\mathfrak{H}$—un des sous-groupes, $\mathfrak{A}$—un complexe invariant d'éléments du groupe $\mathfrak{G}$, $\mathfrak{S}$ et $\mathfrak{S}'$—deux systèmes d'éléments de $\mathfrak{G}$. Si pour chaque élément A du complexe invariant $\mathfrak{A}$ on a*

$$\mathfrak{S}A = \mathfrak{S}' \text{ et } \mathfrak{S} \subset \mathfrak{G}$$

le groupe $\mathfrak{G}$ possède un diviseur normal.

Le théorème III contient à son tour comme cas particulier la proposition suivante démontrée par A. Koulakoff et A. Ditzman [1].

Soient $\mathfrak{S}$ et $\mathfrak{S}'$ deux systèmes contenant le même nombre fini d'éléments différents du groupe $\mathfrak{G}$ et ne coïncidant pas avec $\mathfrak{G}$. Soit $\mathfrak{A}$ un certain complexe invariant d'éléments du groupe $\mathfrak{G}$ contenant au moins un élément qui diffère de l'unité.

Si le produit $\mathfrak{S}\mathfrak{A}$ ne contient que des éléments du système $\mathfrak{S}'$, le groupe $\mathfrak{G}$ n'est pas simple.

En effet, il est facile à voir que la proposition citée est le théorème III pour le cas particulier, où les systèmes $\mathfrak{S}$ et $\mathfrak{S}'$ ne contiennent qu'un nombre fini d'éléments.

En effet, il suit de ce que le nombre d'éléments des systèmes $\mathfrak{S}$ et $\mathfrak{S}'$ est le même et de la condition que le produit $\mathfrak{S}\mathfrak{A}$ ne contient que des éléments du système $\mathfrak{S}'$ que pour chaque élément A du complexe invariant $\mathfrak{A}$ on a l'égalité

$$\mathfrak{S}A = \mathfrak{S}'$$

donc la condition du théorème III est vérifiée.

En concluant j'adresse mes profonds remerciements à M. le professeur W. K. Turkin qui m'a guidé dans le présent travail.

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[1] C. R. Acad. Sci. URSS, III, No. 1 (1935).

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PHYSICS

ON SECONDARY MESOTRONS

By V. VEKSLER and N. DOBROTIN

(Communicated by S. I. Wawilow, Member of the Academy, 28. VI. 1939)

In the light of the experimental evidence obtained in our preceding work (1) through the use of proportional counters we arrived at the conclusion that in cosmic rays there actually exist secondary mesotrons possessing a rather low energy. Inasmuch as this investigation was carried out with the help of a new, insufficiently studied method, we have conducted supplementary experiments, with a view to bringing out the characteristic properties of proportional counters. Already in the course of the very first experiment with proportional counters we succeeded in ascertaining the fact that a sufficiently intensive bombardment by gamma-rays Ra calls forth impulses even in the case when the counters are switched into the coincidence scheme. This suggests the possibility of a separate rapid electron causing an effect even in the case when the mean value of the coefficient of gas amplification falls by far short of the value necessary for the working of the scheme. We, however, considered the probability of a record being taken of a separate electron to be so small as in no way to affect the results obtained. The soundness of this conclusion found evidential support in rough qualitative experiments with the bombardment of proportional counters by small amounts of radium preparations.

In order to elucidate this point with greater detail, we have in a series of experiments estimated the probability of recording of α-particles, as well as Compton's electrons by a separate proportional counter (in the subsequent for the sake of brevity we shall designate this probability by α). The experiments have shown that with normal working sensitivity (with which curve *1* of Fig. 1 in the cited paper was obtained) α has for a rapid electron (with an energy of several hundreds kV and higher) a magnitude of the order of 0.02—0.05, i. e. it is not a vanishingly small magnitude. Besides this it was found that α diminishes with a decline in the sensitivity of the set-up at a slower rate than we supposed formerly; so, for instance, with a twofold decline of sensitivity α changes approximately 4 times as much. With a fall in the energy of the electrons (with an increase in the ionization produced by them) α is liable to grow. We have here to deal with the circumstance that for the coincidences that are not eliminated by the interlying filler, the dependence upon the thickness of the lead located above the counters is represented in the form of an ordinary Rossi curve (curve *2*, Fig. 2). This signifies that at least a very appreciable share of the coincidences is caused by groups of electrons, i. e. the proportional counters are indeed endowed with selectivity with respect to great ionizations.

In connexion with these results we repeated the experiments with bombardment by γ-rays of proportional counters included in the coincidence scheme. The intensity of the bombardment was greater in this case than in the experiments described in the paper cited. At the same time the preparation was not placed along the axis of the counters as had been done before, but opposite the slits in the boxes, i. e. under conditions which were the most favourable for recording Compton electrons. These experiments have shown that the availability of radium appreciably increases the number of coincidences eliminated by the interposed filler.

Thus, the conclusion that the radioactive background in the laboratory cannot play any part whatever in our experiments proved to be erroneous*. Yet, taking into consideration the dependence of the number of strongly absorbed particles upon the thickness of the lead placed above the proportional counters, we are able to fix a certain lower limit to the effect for which cosmic radiation is responsible. The reduction in the number of particles at the origin of the curve (curve *1*, Fig. 2) is likely to be caused to a considerable extent by radioactivity, however the observed increase in the number of the filtrated particles with the growth of the thickness of the lead from 1.5 to 25 cm can in no way be called forth by radioactivity. In order to provide a more reliable confirmation to the effect of the increase in number of filtrated particles under a great thickness of lead we repeated the experiments. Measurements were effected of the number of particles filtrated by an interlayer of 0.8 g/cm² of Al, with 1.5 and 17 cm of lead placed above the proportional counters. Measurements were performed over a period of 13 days. The results are summed up in Table 1.

Table 1

1.5 cm Pb above the counters		17 cm Pb above the counters	
Without interlayer	With interlayer of 0.8 g/cm² Al	Without interlayer	With interlayer of 0.8 g/cm² Al
1101	860	742	435
Effect: 241±44.3		307±34.2	

In considering the data of the table due account should be taken of the fact that with the increase of the thickness of Pb from 1.5 to 17 cm the number of coincidences caused by radioactivity must necessarily decrease in the same proportion, as does the number of impulses in a separate group of counters, i. e. according to our data by 9%.

Making use of the numerical values from Table 1, it will be possible to evaluate the lower limit of the number of filtrated particles due to cosmic radiation.

The data obtained with the help of the new set-up lend additional qualitative support to these results.

Here the I group consists of 5 counters of the Geiger-Müller system connected in parallel, the II and III groups both consist of 5 proportional counters (the proportional counters are the same as in the previous work). The dimensions of the Geiger-Müller counters were made to be the same as those of the proportional counters. The thickness of the brass walls measured 0. 5 mm.

By means of this set-up measurements were carried out of the number

* In the experiments with back showers the radioactive background could not play any part whatever, in so far as there existed an aluminium interlayer of 0.5 g/cm² between the counters.

of triple coincidences both without an interlayer between the proportional counters and with an interlaid filler (0.8 g/cm² of Al). To preclude the appearance of triple coincidences caused by electrons from radioactive contaminations, a 1 mm lead plate was inserted between the Geiger-Müller and the proportional counters. In one series of experiments a plate of 15 mm lead was used instead of the 1 mm plate. Above the counters various thicknesses of Pb could be placed. In order to obviate any possible fluctuations in the sensitivity of the set-up, the measurements (just as in the case of double coincidences) were alternated at a period of 6 min. The respective results are given in Table 2.

Table 2

Lead	Without Pb		1.5 cm Pb above the counters		17 cm Pb above the counters		17 cm Pb above the counters, 1.5 cm Pb between the G.-M. and the proport. counters	
Total number of counted coincidences	Without interlayer	With interlayer	Without interlayer	With interlayer	Without interlayer	With interlayer	Without interlayer	With interlayer
	2012	1857	1739	1763	3385	3128	1047	1057
Effect	155 ± 64		-24 ± 50		257 ± 81		-10 ± 46	

When there were no Pb above the counters and when there were 17 cm Pb above the counters, a decrease in the number of coincidences upon insertion of an interlayer was invariably found to take place. Thus, for instance, the experiments with 17 cm lead lasted 24 days. During this period 20 days gave a positive effect, and only 2 days—a small negative one (for 2 days the effect was equal to zero). Deviations from the mean effect over the whole range of experimental days square well with the range of statistical error.

From Table 2 it will easily be seen that notwithstanding the fact that the described set-up with triple coincidences fails to be equivalent to the former arrangement with two groups of proportional counters, yet the results proved to be qualitatively the same.

The radioactive background of the laboratory could tell upon the set-up with triple coincidences only through chance coincidences of discharges in the Geiger-Müller and the two proportional counters. Control experiments showed the number of such coincidences to be 4—5 times less than the observed effect.

As evidenced by special experiments, the effect cannot be accounted for by the absorption of the electrons of cosmic rays in the aluminium interlayer.

A comparison of Table 1 and the results obtained with the new set-up (with triple coincidences) confirms the main conclusions arrived at by us in the foregoing works.

A more detailed discussion of the results will be provided in the subsequent.

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PHYSICS

DECAY OF LUMINESCENCE IN CERTAIN CLASSES OF LUMINESCENT SUBSTANCES (Al_2O_3Cr, CdI_2MnCl_2, Zn_2SiO_4Mn)

By V. N. ALIAVDIN, V. V. FEDOROV and V. L. LEVSHIN

(Communicated by S. I. Wawilow, Member of the Academy, 31. VII. 1939)

Investigations of the law underlying the luminescence decay provide valuable information on the mechanism of luminescence and in a number of cases play an important part in establishing the character of a luminescence. Thus, for instance, the investigations of the luminescence decay in uranyl salts performed by E. Becquerel (1), S. I. Wawilow and also by one of the authors of the present paper (2), as well as those by F. Perrin and R. Delorme (3) furnished proof of the exponential course of decay for these substances, connected with the monomolecular character of the luminescence process; the investigations conducted by R. Coustal (4), V. Levshin, V. Antonov-Romanovsky and S. Friedman (5,6,7) ascertained the hyperbolic character of the decay for zincous and alkali-earth phosphors associated with the emission of electrons in these phosphors at the moment of their excitation and, accordingly, with the bimolecular character of the luminescence of these substances; investigations of the luminescence decay in saccharine phosphors carried out by S. I. Wawilow and A. S. Shishlovsky (8), as well as those performed for boric phosphors by L. Vinokurov and V. Levshin (9), proved the monomolecular character of the luminescence of these substances, and at long last the work accomplished by V. Levshin and E. Rikman (10) consisting in measurements of the decay of striated luminescences in alkali-earth phosphors activated by samarium, testified to the similarity of the mechanism of luminescence of these phosphors with that of ordinary alkali-earth phosphors activated by heavy metals which give broad emission bands.

The present investigation is an outgrowth of the works mentioned above. It has for its purpose to determine the course of the luminescence decay in certain substances left hitherto unexamined on this score (or insufficiently investigated), and accordingly aims at establishing the nature of the process involved. The exponential course of the decay points to a well developed process taking place within the center of luminescence; while the hyperbolic course is indicative of recombinatory character of the process, i. e. it corresponds fully to a complete separation of electrons from ions of the crystalline lattice and to their further recombination with other excited centers of luminescence.

1. O. Deutschbein (11) has conducted highly interesting spectrum analysis investigations of the luminescence of chromium-aluminates (Al_2O_3Cr).

The luminescence has a resonance character, in so far as the position of short wave-length bands of absorption and radiation coincide. The spectrum consists of a number of lines and bands peculiar to chromium ions, the main lines lying within the red region. The law underlying the decay of the luminescence was not however investigated by Deutschbein. The luminescence was found to be but of short duration.

In our investigations we devised a special phosphoroscopic apparatus for examining the course of the decay. A disc with the phosphorescent substance running in a continuous band along its edges was mounted on the axis of a motor giving about 100 r. p. s. The disc was placed in a special chamber having on its outer side 12 equally distanced apertures running along the circumference. The apertures were in this way made to lie above the band with the phosphorescent substance. The illumination of the phosphor was effected through one of the apertures, while through the other ones different moments in the decay of the luminescence were observed. A photometer of a special design which could be set opposite any desired aperture of the chamber was installed on the rigid extension of the motor axis. The excitation was produced from a strong incandescent lamp and passed through a black glass capable of transmitting the nearer ultraviolet.

The luminescence was studied within the range from 0 up to 0.12 sec. The first measured point corresponds to a moment of 0.02 sec. In plotting the results of the measurements on the diagram in the form of co-ordinates (t, lg I), we obtain a straight line passing through the origin of the co-ordinates (Fig. 1). The observed variations of intensity run into 2000-fold. As will be seen from Fig. 1, the course of the decay is rigorously exponential; the mean duration of luminescence $\tau=0.016$ sec.

The obtained data testify to the monomolecular character of the process (there is no reason to suppose the existence of an excess of free electrons within the preparations of the given type, under which conditions the exponential law of decay might be observed also with the case of complete separation of electrons).

2. The second type of luminescent substances consisted of lamellar phosphors obtained from calcium iodide and manganous chloride. A high content of both components should be regarded as their essential characteristic: manganous chloride introduced into these substances is taken in large amounts ranging from 5 to 50%; in all appearances it should be classed rather under the head of a second base than as a promoter. Kutzelnigg [12] who was the first to obtain these varieties maintains that their luminescence is connected with their lamellar structure. Luminescent preparations of this type are obtainable by means of heating the mixture up to 150—200°, while the mixture may be made simply by way of mixing or simultaneous precipitation of both components from the solution. Luminescent preparations are also obtainable by strongly rubbing the mixed powder. All these methods were applied by us in the preparation of the materials in question.

The spectrum of the luminescence was determined spectrographically. It represents a broad continuous band lying between 640—720 mμ. The spectrograms were taken on plates sensibilized by dicyanine.

Heating affects somewhat the yield of luminescence. Taking the yield at 26°C as 100, we obtain the following variations of the yield with temperature:

26	62	92	134
1.00	0.89	0.72	0.62

Fig. 2 and 3 show the decay in cadmium-manganous phosphors with the help of co-ordinates (t, lg I). As is seen from the diagram, the decay

proceeds along the exponential function with a mean duration of $\tau = 5.8 \cdot 10^{-4}$ sec.

The process has been traced within the range from 0.001 to 0.004 sec. Within this time interval the intensity of the luminescence varied 220-fold. The straight line passes however well through the origin, because of which the total fall of intensity obeys the exponential law, provided its decline is not less than 1000 times.

Fig. 2 refers to the preparation containing 10% of $MnCl_2$. In Fig. 3 are to be found the results of measurements of the decay of luminescence with varying content of $MnCl_2$ (from 5 to 50%) and with different methods of preparation. The respective data are shown by means of different conventional symbols. The decay throughout obeys the exponential law, the duration of luminescence being independent of the content of $MnCl_2$.

3. The decay process in villemites (Zn_2SiO_4Mn) was found to be more complex. The authors investigated two preparations activated by Mn. The

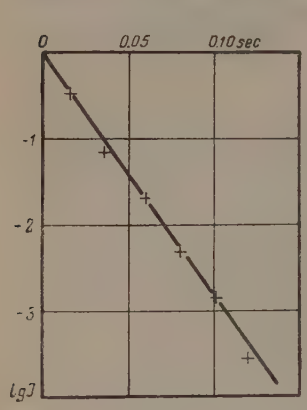

Fig. 1.

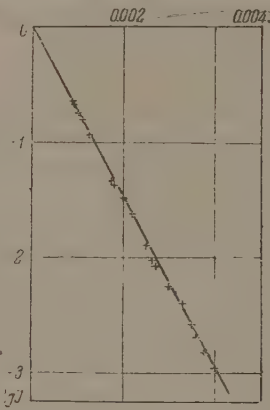

Fig. 2.

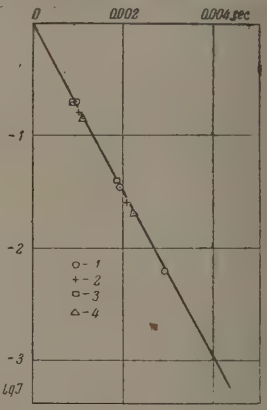

Fig. 3.

earlier stages of decay up to 0.12 sec. were investigated with the help of the above-mentioned phosphoroscope, while the later stages ranging from 0.3 to 20 sec. were studied by direct measurements with a photometric set-up. In the first case the excitation was produced by close-range ultraviolet light (from 380 to 300 mμ) emitted from an automobile headlamp burning with overglow, whose visible part of emission was cut off by means of a black filter. The results of the measurements with a duration of excitation of 0.004 sec. are represented by curve *I* (Fig. 4). Fig. 4 is given in co-ordinates (t, $\lg I$); the absence of linear connexion between the logarithm of intensity and time points to a departure from the exponential law of decay. However, owing to the existence of an admittedly lengthy process in the given instance, the supposition could be made that in the earlier stages a break in the exponential course of decay actually occurs due to the superimposition of this very lengthy process. It is well known that the less is the duration of decay, the sooner is a state of equilibrium attained between excitation and radiation with given brightness of exciting light. Therefore, with a view to weakening the prolonged process, the duration of excitation was reduced 4 times, i. e. it was brought down to 0.001 sec. Under these conditions the decay measurements gave curve *II* in Fig. 4, which approaches closely enough the theoretical straight line *A*, expressing the exponential course of decay:

$$I = I_0 e^{-\frac{t}{0.0106}}. \qquad (1)$$

The obtained result agrees well with the data recently obtained by R. Nelson, R. Johnson and W. Nottingham on the early stages of decay in villemite with cathode excitation ([13]). With the aforesaid excitation at the earlier stages the decay proceeds also in approximate accordance with the exponential law with $\tau \approx 0.01$. The values of the deviations from the exponential law are nearly of the same magnitude as was observed by us.

In investigating the later stages of decay, the excitation was effected through a quartz objective without filters from a mercury quartz lamp. All the ultraviolet lines of the mercury lamp served in this case as the exciting agents, yet the greatest significance belonged to the resonance line 253.7 mμ. Luminescence of long duration arising under the influence of separate more closely spaced ultraviolet lines was found to be of low intensity; similarly, excitation through a black filter proved to be insufficiently intensive for the purpose of testing the decay within a broad range of brightness variations. (The results of decay measurements in the distant stages, as stated below,

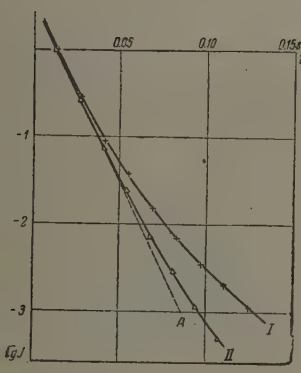

Fig. 4.

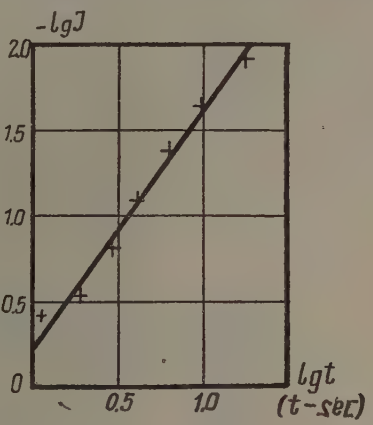

Fig. 5.

were obtained with another sample of the preparation and not with that used in the measurements of the nearer stages of the process). Measurements within the time interval from 0.3 to 20 sec. showed a hyperbolic course of decay. In Fig. 5 is to be found a straight line corresponding to the equation

$$I = At^{-1.41}. \qquad (2)$$

In the interval from 0.3 to 20 sec. the first process may be considered as termined, since by the time of 0.3 sec. the brightness of its luminescence falls 10^{12} times.

Formula (2) cannot be extrapolated to the initial stages, since in the early stages it has to be replaced by a relation of the type

$$I = \frac{a}{(b+t)^{1.41}}. \qquad (3)$$

The respective bend at the ends of the straight lines belonging to the initial stages of decay was detected in a number of measurements.

The sum total of the adduced data testifies to the fact that the luminescence of villemite consists of at least two processes: a short-time process, an exponential one with a mean duration of the order of 0.01 sec., and a prolonged process, a hyperbolic one with a decay index $\alpha \leqslant 2$.

Preliminary experiments have shown that a rise in temperature is liable to reduce the value of α in the case of a lengthy process and in certain cases to enhance the intensity of luminescence materially. The character of the influence exercised by temperature upon the integral emission of villemite depends, as recently shown by Vinokurov, Ivanov and one of the authors, upon the wave-length of the exciting light. A detailed investigation of these temperature effects is at the present time under way.

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PHYSICS

ON THE METASTABLE LEVELS OF THE GADOLINIUM NUCLEUS

By D. ALKHAZOV, I. GUREVICH, I. KOURTSCHATOW and V. RUKAVISHNIKOV

(Communicated by V. G. Chlopin, Member of the Academy, 4. VIII. 1939)

Evidence recently produced in studying the nuclear isomerism and which has made the basis for an adequate interpretation of this phenomenon is that metastable states with a comparatively small excitation energy are present in the nucleus (1). The isomeric nucleus, when it has been excited to the metastable level, passes over to the ground state emitting, as a rule, electrons of internal conversion (2). The methods of artificial radioactivity which serve

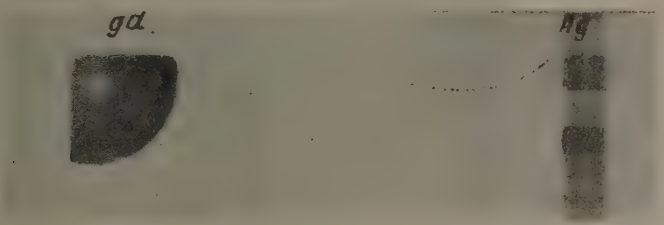

Fig. 1.

to study the properties of the metastable states from isomeric phenomena, can be applied only when the life time of the metastable nucleus amounts to several seconds at least. Theoretically speaking, the life of the nucleus may vary over a much wider range, from 10^{-3} sec. to any length of time.

New possibilities for the detection of the metastable states are opened by the study of the radiation accompanying the nuclear reaction proper. If the resulting nucleus possesses a metastable level of short life, the probability of internal conversion processes will increase, and the reaction will be accompanied by the emission of soft electrons.

It may be assumed that the metastable state is common to most, if not all, of the nuclei. On the assumption that these states are also inherent to the gadolinium, we proceeded to the investigation of the nature of the radiation emitted by the said element upon the capture of slow neutrons.

When judging of the metastable states by the soft radiation it must, however, be borne in mind that, owing to the considerable absorption of the electrons, this radiation is emitted only from an extremely thin layer of the substance; therefore, the intensity of the soft radiation, as compared with that

of other radiations accompanying the nuclear reaction (for instance, that of the γ-rays), will be considerable only on condition that the nuclear reaction takes place in sufficiently thin layer. In this respect gadolinium, irradiated with neutrons, presents a very suitable subject of investigation, the coefficient of absorption of the thermal neutrons in Gd being rather low (a layer of 7 mg cm^2 will bring down the intensity of the slow neutrons to half its initial value).

The neutrons were obtained using the D+D reaction in the cyclotron described previously ([3]). The neutrons, slowed down by a paraffin block, impinged on a layer of gadolinium which was in contact with a sensitive X-ray film. Finely powdered gadolinium oxide was mixed with pure alcohol; the suspension so formed was poured into brass cups, which were depressions in a special dark-slide. After the alcohol had evaporated, a uniform thin layer of gadolinium oxide was obtained which adhered to the brass base without the aid of any cement. The surface density of a layer of this kind is about 4—5 mg/cm^2.

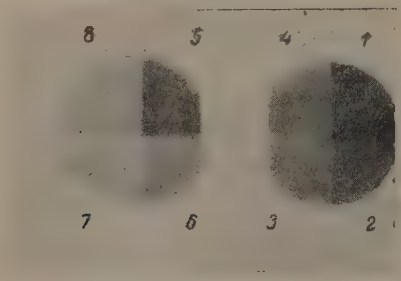

Fig. 2.

The first series of experiments (with a 10 to 12-hour exposure) showed the presence of an intense soft radiation from gadolinium irradiated with neutrons, the same was observed by Kourtschatow by means of a counter in a previous research. Photograms for gadolinium and silver, both irradiated under similar conditions, are reproduced in Fig. 1. The considerable blackening produced by the gadolinium shows that the effect is associated with the capture of neutrons by the strongly absorbing isotope of this element. In the case of gadolinium the blackening is restricted to the part of the emulsion in its immediate contact. We may conclude that practically all the active radiation is absorbed in a 10^{-2} cm thick layer of the celluloid of the X-ray film.

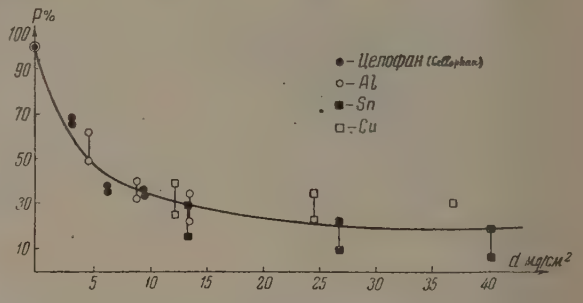

Fig. 3.

In order to elucidate the nature of this radiation and to make a rough estimate of its hardness or penetrating power, we proceeded to the study of the absorption of the soft radiation in different absorbers. For this purpose, absorbers of cellophane, aluminium, copper and tin of various thicknesses were placed between the film and the gadolinium layer. The blackening of the film produced by the various absorbers is illustrated in Fig. 2, showing the photograms of the soft radiation from gadolinium passed through cellophane or through aluminium. Sectors 1 and 5 refer to the direct action of the radiation on the X-ray film; sectors 2, 3 and 4 refer to the absorption in cellophane, the surface density being 3.16, 9.48 and 6.32 mg cm^2, respectively; sectors 6, 7 and 8—to the absorption in aluminium with surface densities of 4.5, 13.5 and 9.0 mg/cm^2, respectively.

The photometrical measurement of the film yielded the absorption curve of Fig. 3. The difference in the blackening of the irradiated and the non-irradiated regions ΔS was determined taking the average opacity of the latter over the whole film. The percentage absorption is obtained by dividing ΔS for the whole film by ΔS_0 corresponding to that part of the radiation which passed through the absorber.

Fig. 3 shows in a convincing way that the soft gadolinium radiation acting on the film is an electron emission. Indeed, if it were of the nature of X-rays, the mass absorption coefficients in aluminium and cellophane would differ 4—5 times for a given hardness, irrespective of any deviations of the film sensitivity from the proportionality law; indeed, the radiation is seen to produce the same blackening whether it has passed through aluminium or through cellophane. The energy of the electron radiation from gadolinium can be evaluated only roughly from the coefficient of absorption in aluminium and is of the order of 100 ekV (with a 4.5 mg/cm² thick Al absorber).

The above results lead us to the assumption that the gadolinium isotope which considerably absorbs the slow neutrons and shows no artificial radioactivity is characterized by a metastable state leading to processes of internal conversion.

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TECHNICAL PHYSICS

ILLUMINATION OF MICROSCOPE

By D. S. ROJDESTVENSKY, Member of the Academy

1. Thousands of people working with a microscope have no leisure to penetrate deeply into the mysteries of optics. Therefore every device in the microscope which facilitates the using of all its optic potentialities is of great importance. The inner qualities of the microscope were brought by Abbé and his followers nearly to the conceivable limit of perfection and simplicity. The illumination of the microscope, however, is still inadequate.

a) The illumination by the sky is unsatisfactory, its brightness being too small (1 stilb). The source of illumination is projected on the object, and the intensity of the source only, not its dimensions, determines the brightness of the image in the eye. Microscopists know that even trying to catch the brightest cloud in the sky it is impossible to illuminate the object sufficiently brightly at great magnifications, especially if it is necessary to lower the aperture of the illuminating beam when viewing a transparent object.

b) The filament of an ordinary lamp is hundred times brighter than the sky (hundred stilbs), but projecting the filament in the object by means of a condenser we reduce it to such an extent that the field of vision becomes too small. Now the projection by a short-focused condenser is necessary in order to get the illuminating pencil not only bright, but also of a very high aperture, equal to the aperture of the object-glass.

c) A ground glass placed before the lamp becomes itself a very wide source of light, but its brightness grows hundred times smaller and becomes insufficient.

d) At the expense of large amounts of energy ($\sim$50 watt) one can make a much wider source of light (several millimeters) than the filament of a lamp and project it on the object. Such illuminators are actually available (a small tungsten strip incandescent under electric current, or «the pointolit», a tungsten globule rendered glowing by an arc in vacuum). They are manufactured by several firms and have a lens system (a collector) which together with the condenser projects the source of illumination on the object (a more proper illumination is by Köhler's method). Optically they are perfect. But there are three drawbacks to their construction: 1) a powerfull source of light is necessarily placed in the proximity of the lens of the collector, and in general in the proximity of the microscope; 2) the optical system is very long (about several decimeters); 3) a large amount of energy is required ($\sim$50 watt). It is therefore impossible to unite this system with that of the microscope into a whole, and the simplicity and automatism of handling available in the upper part of the microscope are here precluded. This is a very essential defect from the practical point of view, which renders the results achieved by the

microscopists nearly 2—3 times less effective. The best of them have been obtained under by far inadequate illumination (see J. Belling, «The Use of the Microscope», 1930).

2. The right way to the improvement of the illumination of the microscope—which, as is shown heraefter, will lead to other improvements of a still greater importance—is based on the fact that the amount of energy required for the brightest illumination of the microscope in most difficult cases is quite insignificant and can be measured in tenths of a watt. It can be 500 times less than it has been indicated above (d).

Since the most difficult case is that of greatest magnification, we will now consider it here: an object-glass 90 × of the aperture 1.25 with an eyepiece 15×, when the field of vision attains a diameter of 0.1 mm. For getting all the brightness of tungsten incandesced to the limit into the whole field of vision, it will be quite sufficient to project on the object a short piece of a filament about 0.2 mm wide and 0.2 mm long, without any diminution or with a small one. That is something like a brilliant point. The incandescence of such a brilliant point will require 3 times less energy than the incandescence of a hand-lantern filament, which is heated by the current of a small dynamo, working under hand pressure. And we must bear in mind that this tungsten filament with 0.3 watt gives the greatest possible brilliancy. In this way we return to the section «b» of the preceding paragraph, but we demand the projection not to be diminished (almost). Besides, the image of the brilliant point on the place of the object must have (in oil) an aperture of radiation equal to 1.25. Consequently the same, or nearly the same aperture is to be taken off from the brilliant point itself.

It is evident that the projecting system must consist principally of two parts: one, taking energy from the source of light with rays of large aperture, and the other, projecting anew the small image, again with a large aperture. As a latter part a reversed object-glass with equivalent aperture (1.25) and magnification (90×) may be taken. The first part must be somewhat different: to begin with its aperture cannot exceed the unity (the source of light not on oil being like its image), secondly, the incandescent brilliant point must be placed before it. Therefore it must be a dry object-glass with a possibly high aperture and especially with a possibly large distance between the source of light at high temperature and the first lens. As those distances are generally very small (parts of a millimeter), the first object-glass must be proportionally (6—7 times) enlarged in all its dimensions. The distance between the brilliant point and the first lens will get as much greater. But then the second (projecting) object-glass must be enlarged in the same way. Then the distance of the image of the projecting object-glass (in oil) from the last lens will be so magnified that the position of the image will be over the glass slide. The object-glass is sometimes used as an optically good condenser, whereby its all dimensions are not enlarged. In this case however the image is so near to the front lens that the object is to be placed on a cover-glass which is 6 times thinner, but this is not advisable on technical grounds. The way out of the difficulty is to increase the object-glass projecting the source image in all its dimensions.

3. Its technical execution is the better, the farther the source of light from the lens. Among the existing dry object-glasses with an aperture 0.85, it is possible to choose such a one (the dimensions of the object-glass being enlarged 7 times), that the distance of the brilliant point from the first lens is equal to 3.5 mm. This makes the solution of the problem technically possible. The incandescent brilliant point may be placed at such a distance from the glass-lens without damaging it. The image of the source of

light will then be diminished with regard to the aperture by $\frac{1.25}{0.85}$, i. e. nearly 1.5 times.

A still better solution was suggested by G. D. Rabinovitch, a specialist in the calculating microscopy: to take for the first object-glass one with the same magnifying power (90×) and aperture 1.25, but with the first front lens (in oil) replaced by an Amici's meniscus (in the air). The aperture will then automatically fall to 0.83 and the meniscus being concave the distance from the source of light to the meniscus glass increases up to 5 mm, when the dimensions of the object-glass are enlarged correspondingly.

The source of light is to be placed in the center of the first (spherical) surface of the Amici's meniscus. This happened to turn out as an unexpected advantage with regard to the technical realization of the source of light. It is easy to blow on the glass wall of the lamp a sphere (radius 3 mm), concentrical to the sphere of the meniscus, and it is also rather easy to place (under the control of a microscope) the brilliant point in the center of the sphere at the wall of the lamp and afterwards to set the lamp in such a way that the brilliant point will appear in the center of the meniscus. Then the concentrical wall of the lamp will not spoil the image of the brilliant point through the whole system. Further calculations may possibly widen the scope for the technical construction of the lamp, as the whole projecting system must not be optically so perfect, as the object-glasses, and the aim in calculation is only to move off the brilliant point from the lens. But the first lens in the shape of Amici's concave meniscus will probably remain unavoidable on technical grounds.

In this way the whole illuminator consists of a brilliant point in the focus of one object-glass, whereas the other object-glass projects this point upon the object on the glass slide. The dimensions of both object-glasses are enlarged 6—7 times.

For routine microscopes the whole system must be greatly simplified. Besides Köhler's system of illumination must be applied, which may be achieved without difficulty. Finally a pancratic system must secure the transition from the illumination of small fields of vision with a high aperture to large fields of vision with a low aperture, as it is the case for the Zeiss's pancratic illuminator. The latter approaches the solution half-way following the method here obtained: a semi-ground glass is used and the loss of energy is only 40 times (4-watt lamp) instead of 500 times.

The complete solution of the problem here formulated will lead to greater achievements than it may appear at the first sight:

1. An illuminator always correctly placed with an abundance of light.

2. This affords the possibility of using eye-pieces with higher degrees of magnifying power. Till now it was considered even by experienced microscopists that such eye-pieces damage the sight; in fact the sight was damaged by the deficiency of light, unavoidable at large magnification, when the illuminators are bad.

3. Even the theorists have up to now submitted to this hunger-ration of light intensity and limited the magnifying power of a microscope by a fourfold value of the resolving power of the eye. But a simple instance shows that the eye requires more. It resolves a minute, that is to say $3 \cdot 10^{-4} \cdot 10 \cdot 100 = 0.3$ cm at a distance of 10 m, but if a lecturer writes on the blackboard letters only 1.2 cm broad, the students although discriminating them without difficulty will be driven to despair by the strain required from their attention. We have the same in the microscopy. The ocular magnifications must and can be made greater. Practice shows it quite distinctly. Historically it has been prevented only by the insufficient brightness of the sky.

4. Plenty of light must lead to one very important improvement of the microscope. At great magnifications the observer looses the orientation, namely the notion which place of the preparation is in the field of vision. It is therefore important as in cinematography to have a small and a large magnification of the object in the field of vision simultaneously, being able arbitrarily to overshade one or another. For instance, to examine simultaneously under two magnifying powers: 90× and 3000×. This may be achieved by dividing the beam at the eye-piece end into two branches which can be brought together again, but used for different magnifications within the interval when they are running apart.

5. It is possible and necessary to give up the illumination by the sky. In the laboratory conditions the light might be taken from a switch. A great advantage of such an illuminator lies in the fact that out of town on excursions a small toy spring-dynamo placed into the microscope itself will give as bright an illumination as is available under most favourable conditions.

6. A complete rejection of the sky-illumination will change the appearance of the microscope and provide a more rational arrangement under the object-table.

7. With the abundance of light from the modern incandescent lamps which have their brightness amounting to thousands of stilbs (as the voltaic arc), a wide and various application of the photography with strictly controlled illumination becomes possible.

The plan outlined here appears to be worth assiduous efforts on the part of those who are concerned with designing, calculating or constructing microscopes. The work in this direction has already started and is now in progress at the State Optical Institute.

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Leningrad State University.
State Optical Institute.

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GEOCHEMISTRY

ARSENIC IN THE APATITES OF THE KHIBINY TUNDRAS

By Z. M. GILEVA and B. N. MELENTIEV

(Communicated by A. E. Fersmann, Member of the Academy, 14. VII. 1939)

There are indications in literature ([1],[2]) as to the presence of arsenic in the Khibiny apatites, but nobody has made its quantitative determination. It is very important, however, to do this and not only in view of the fact that the study of the apatite body in different khibinian deposits would be more complete with such investigation. There is also a practical side to the question, since applicable amounts of arsenic in the apatite would seriously interfere with its use in food industry after some technological treatment.

The principal difficulty in determining small quantities of arsenic consists in the presence of a large quantity of phosphoric acid, therefore the authors have chosen the Tiele-Bugo reagent, reducing arsenic to metal and having no influence upon phosphoric acid. The Tiele reagent allows to determine nephelometrically, according to Snell ([3]) and Fhuret ([4]), from 5.10^{-4} to 1.10^{-4} mg of arsenic in 1 cm^3 of solution.

The determination was carried out as follows: 10 g of apatite selected by means of a binocular lens were decomposed by 40 cm^3 of hydrocloric acid free of arsenic, sp. grav. 1.19, in a retort with a ground-in stopper, in a water bath at 60°C. In an hour the apatite was completely decomposed. Only a small insoluble residue of aegirite remained which could not be removed by the most thorough selection.

Upon cooling the solution was filtered into a 100 cm^3 beaker, and 40 cm^3 of Tiele's reagent were added (20 g of sodium hypophosphite are solved in 20 cm^3 water, and 200 cm^3 HCl, sp. gr. 1.19, are added; the precipitated sodium chloride is filtered off through cinder-wool). After heating during an hour the volume decreased to 50 cm^3; this corresponds exactly to the concentration at which the salts are not yet precipitated from a 10-g apatite sample.

A solution with known content of arsenic was subjected to a similar treatment to serve as standard for comparison in a Dubasque colorimeter modified by the author to a nephelometer. The readings were checked by a Mikhalchuk ([5]) objective photo-nephelometer.

In order to check the results obtained known quantities of arsenic have been added to the 10-g sample, which afterwards have been detected again by the above method.

Table 1 shows the suitability of the method chosen for the estimation of arsenic in apatites.

The next table shows the arsenic content in apatites taken from eight deposits; from the worked deposits five specimens have been taken—three from the Kukisvumchorr and two from the Yukspor ([6]).

Table 1

Test No.	Introduced As in g		Total As	Obtained As in g	Deviations	
	as salt	with apatite			in g	as recalculated to a 1-g sample in g
56	0.00018	0.00002	0.00020	0.00019	—0.00001	—1
57	0.00015	0.00002	0.00017	0.00017	+0.00000	±0
58	0.00014	0.00002	0.00016	0.00018	+0.00002	+2

Table 2

Type of specimen	Contents As in %			Average As in %	As in g per g P_2O_5
	I determ.	II determ.	III determ.		
Mt. Kukisvumchorr (coarse-grained) . . .	0.00016	0.00016	—	0.00016	3.9
Mt. Kukisvumchorr (medium-grained)	0.00024	0.00022	0.00022	0.00023	5.6
Mt. Kukisvumchorr (fine-grained)	0.00022	0.00024	0.00024	0.00023	5.6
Mt. Yukspor, lot 7 . .	0.00018	0.00018	0.00013	0.00016	3.9
Mt. Yukspor	0.00020	0.00016	0.00018	0.00018	4.4
Mt. Rasvumchorr . . .	0.00006	0.00006	0.00006	0.00006	1.5
Mt. Kuelpor	0.00010	0.00010	0.00020	0.00013	3.2
Mt. Nyorpakhk	0.00024	0.00024	—	0.00024	5.9
Mt. Poachvumchorr . .	0.00006	0.00008	0.00008	0.00007	1.7
Mt. Takhtarvumchorr .	0.00022	0.00008	0.00019	0.00016	3.9
Gorge between the Yukspor and Aeveslogchorr	0.00012	0.00012	0.00014	0.00013	3.2

On the basis of these data it is impossible to establish the dependence between the arsenic content and the type of deposit.

It will be obvious that the Khibiny apatites contain insufficient amounts of arsenic to prevent their use as raw material in the technological processes employed in food industry.

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GEOCHEMISTRY

CHEMICAL COMPOSITION OF THE KHIBINY APATITES

By M. I. VOLKOVA and B. N. MELENTIEV

(Communicated by A. E. Fersmann, Member of the Academy, 21. VIII. 1939)

Up to the present nine analyses are known of Khibiny apatites, showing their composition with sufficient precision ([1],[2],[3]). They embrace the chief grades of apatite from commercial deposits (Kukisvumchorr, Yukspor and Rasvumchorr).

In order to elucidate the chemical composition of apatites of all known deposits in the Khibiny Tundras during 1936 and 1937, A. N. Labunzev and the scientific staff of the Kola Base examined the principal and most interesting apatite deposits, from which samples were taken of apatite types characteristical of each deposit. On the whole twelve samples have been taken from eight deposits. Afterwards complete analyses have been made of the apatites according to specially developed schemes proposed by I. D. Borneman and B. N. Melentiev.

Description of Samples

Specimen No. 1. Mt. Kukisvumchorr, Mine, lot II. Badly cemented light-green apatite crystals up to 11—14 mm in length and 3—4 mm in diameter, frequently with well preserved pyramid faces. Separate inclusions of nepheline and thin needles of aegirite are encountered. Analyst B. N. Melentiev.

Specimen No. 2. Mt. Kukisvumchorr, Mine, lot I, horizon 511. Medium-grained comparatively slightly cemented, light-green apatite varying in grade from tenths of a mm to 3—4 mm. Idiomorphic apatite grains are sometimes encountered with a deeper green colouring up to 15 mm in length and 5—6 mm in diameter. Locally indistinct nepheline and endialyte spots are encountered as well as accumulations of aegirite and brown sphene. Analyst E. I. Zakharov.

Specimen No. 3. Mt. Kukisvumchorr, Mine, lot IV, horizon 473. Easily crumbling fine-grained white saccharoidal apatite. Inclusions of nepheline are observed up to 1.5—2 cm in diameter, and brown sphene. Accumulations of thin pyroxene needles are frequently encountered. Analyst I. D. Borneman.

Specimen No. 4. Mt. Yukspor, Mine, lot VII, adit No. 5. Easily crumbling fine-grained saccharoidal apatite, pierced by needles of greenish apatite. Separate inclusions of sphene. Accumulations of pyroxenes and rare fine grains of titanomagnetite are encountered. Analyst E. I. Zakharov.

Specimen No. 5. Mt. Yukspor, Mine, open workings, first bench from below, to the right of the adits. Coarse-grained apatite with slight greyish tinge. Separate inclusions are observed of well-developed brown sphene and comparatively thin needles of pyroxene. Analyst M. I. Volkova.

Specimen No. 6. Mt. Rasvumchorr. 1st west ditch. Medium-grained apatite of a light-green colour. The grain size varies from tenths of a mm to 2—3 mm. Nepheline, accumulation of pyroxenes and brown sphene are encountered. Analyst M. I. Volkova.

Specimen No. 7. Mt. Rasvumchorr, Apatite cirque, 2nd ditch. White fine-grained apatite, pierced by thin needles of green idiomorphic apatite up to 8—12 mm

Oxides \ Sample No	1	2	3	4	5	6	7	8	9	10	11	12
P_2O_5	40.51	40.95	41.03	40.92	40.80	41.16	40.91	40.58	40.77	38.33	38.65	40.57
As_2O_5	0.00016	0.00023	0.00023	0.00016	0.00018	0.00006	not det.	0.00013	0.00024	0.00007	0.00013	0.00016
V_2O_5	0.001	not det.	not det.	not det.	0.001	not det.	» »	not det.	not det.	not det.	not det.	not det.
SiO_2	0.21	0.41	0.28	0.33	0.26	0.42	0.40	0.48	0.27	1.55	0.52	0.21
TiO_2	0.00	0.00	not det.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ZrO_2	0.00	0.001	0.001	not det.	0.001	0.001	not det.	0.001	0.001	0.001	0.01	not det.
ΣTR_2O_3	0.82	1.19	0.87	1.20	0.80	1.08	1.10	1.24	0.88	3.22	4.90	1.75
Fe_2O_3	0.25	0.10	0.05	0.08	0.08	0.17	0.14	0.09	0.12	0.09	0.12	0.12
Al_2O_3	0.02	0.19	not det.	0.10	0.12	0.08	0.34	0.20	0.34	0.34	0.06	0.10
CaO	52.48	52.51	53.35	52.27	53.17	52.94	52.19	51.81	52.92	42.38	47.51	47.70
SrO	2.94	2.51	2.43	2.71	1.75	1.75	2.50	3.25	2.11	11.42	5.58	6.69
BaO	0.00	0.00	not det.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	not det.	0.00
MgO	0.05	0.12	» »	0.09	0.08	0.14	0.10	0.07	0.08	0.05	0.10	0.10
MnO	traces	0.05	» »	0.03	0.01	0.01	0.04	0.04	0.03	0.05	0.02	0.03
Na_2O	1.21	0.14	0.08	0.35	0.30	0.27	0.13	0.05	0.41	0.13	0.64	0.36
K_2O		0.08	0.09	0.20	0.08	0.09	0.08	0.02	0.11	0.07	0.08	0.04
$+H_2O$	0.18	0.15	0.05	0.11	0.19	0.18	0.14	0.10	0.13	0.28	0.13	0.10
F_2	2.83	2.47	3.40	3.44	3.32	3.35	3.54	2.82	3.22	3.73	3.20	3.12
Cl_2	0.00	not det.	not det.	not det.	0.00	0.00	not det.	not det.	0.00	0.00	traces	traces
Σ	101.50	100.87	101.83	100.96	101.64	101.61	100.75	101.75	101.39	101.67	101.49	100.89
Minus O_2 equiv. F_2	1.19	1.04	1.43	1.45	1.39	1.41	1.49	1.13	1.35	1.57	1.34	1.31
Σ	100.31	99.83	100.20	100.38	99.57	100.23	100.12	99.62	100.04	100.10	100.15	99.58
Specific gravity . .	3.237	3.314	3.240	3.240	3.221	3.233	3.240	3.247	3.220	3.355	3.323	3.295

Note. In analysis No. 1 SO_3=0.00% and heavy metals=0.00%.

in length and 1 mm in diameter. Very frequently accumulations of pyroxenes are encountered, brown sphene is rarely observed. Analyst E. I. Zakharov.

Specimen No. 8. Mt. Kuelpor, south ditches. White fine-grained apatite, with frequent inclusions of nepheline and pyroxenes. Analyst E. I. Zakharov.

Specimen No. 9. Mt. Nyorpakhk, south-west test pit. Light green medium-grained apatite. Inclusions of nepheline and brown sphene are observed. Separate fine grains of titanomagnetite. Analyst M. I. Volkova.

Specimen No. 10. Mt. Poachvumchorr, western slope, $^1/_2$ km northward from the Eastern pass. Rather compact greenish-yellow apatite. Contains a considerable quantity of sphene and pyroxene inclusions. Analyst E. I. Zakharov.

Specimen No. 11. Gorge between the Yukspor and Aeveslogchorr mountains. Yellowish-green compact cemented apatite. Pyroxene inclusions are observed together with sphene and separate grains of lamprophyllite and astrophyllite. Analyst M. I. Volkova.

Specimen No. 12. Mt. Takhtarvumchorr, Molybdenum prospect, albite veins, outcrop № 1. Yellow with a slight greenish tinge, easily crumbling apatite. Associated with albite, pyroxene, aenigmatite and molybdenite. Analyst M. I. Volkova.

The samples were crushed and afterwards the apatite was carefully graded by means of a binocular lens.

P_2O_5, CaO, SrO, TR_2O_3, Fe_2O_3, Al_2O_3, TiO_2 and MgO have been determined in one sample according to three different schemes of systematic analysis ([4]); MnO—colorimetrically; V_2O_5—according to Sandell ([5]); F_2—according to Willard-Winter, the method being modified by the Scientific Institute of Fertilizers ([6]); SiO_2—according to Ode-Schrenk ([7]); $+H_2O$—according to Gooch; zirconium has been determined spectroscopically; F_2 and SiO_2 in all specimens have been determined by M. I. Volkova: As_2O_5 ([8]), $+H_2O$ and specific gravity—by Z. M. Gileva.

The conclusion to be drawn from the analytical data is that in respect of the chemical composition too all the apatite deposits of the great arc present a uniform whole. The geologically isolated deposits of Poachvumchorr, Takhtarvumchorr and Aeveslogchorr were found in all respect to be different from all other apatites, chiefly owing to the higher content of rare earths and strontium. The latter fact allows it to be emphasized that the temperature range of apatite formation in these deposits was lower than during the crystallization of apatite in the great arc ([9],[10]).

Detailed investigation of the strontium apatite, this mineral deserving to be isolated into a separate mineralogical species under his own name (saamite), is in progress at the Kola Base.

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CHEMICAL TECHNOLOGY

ISOLATION OF RARE EARTHS FROM APATITE IN THE COURSE OF ITS ACID TREATMENT

By S. I. VOLFKOVICH, Corresponding Member of the Academy, and A. I. LOGINOVA

A very important question from the technological point of view is whether or not the rare earths enter into the composition of the apatite and other minerals from the Khibiny apatite-nepheline rocks. This question may be regarded at present as definitely solved: the rare earths give isomorhous replacements of calcium in the apatite lattice (1). Consequently, they are liable to modification in any technological process of apatite decomposition, be it an acid, thermal or alkaline-thermal one.

The Khibiny apatite concentrate is known to contain up to 1.1% rare earths, a considerable part of which is taken up by cerium. This means that the process of manufacturing fertilizers and salts from the Khibiny apatite involves a heavy waste of the valuable rare earths, which runs into thousands of tons yearly.

From this standpoint the decomposition of the apatite by the nitric acid should be recommended, since the extraction of rare earths in this process is more complete and the commercial effect higher, not only the rare earths, but also the phosphoric acid, calcium and fluorine being most effectively turned to account. This process (2), however, though developed in detail has not yet been realized in industry; at present the construction of the first plant is projected according to this plan.

The processes of apatite decomposition with sulphuric acid widely used in the chemical industry do not meet the requirements of a complex utilization of the raw material, since a considerable part of the valuable components of apatite as well as the sulphuric acid used for its decomposition are scarcely utilized if at all. If the production of phosphoric acid runs according to the equation

$$Ca_5F(PO_4)_3 + 5H_2SO_4 \cdot aq = 3H_3PO_4 + HF + \underbrace{5CaSO_4 \cdot aq}_{\text{phosphogypsum}}$$

and the further process is to obtain concentrated fertilizers and different salts (by way of basic neutralization), then the rare earths partly get into the so-called phosphogypsum (so far regarded as waste), and partly into the final product, where they are as good as lost.

Physical-chemical data on the individual and joint solubility of rare earth oxides in H_2SO_4, H_3PO_4 and HF and their salts* are not available. Therefore

* A physical-chemical analysis of the solubility of rare earths both in the above acids and in HNO_3 and HCl is the immediate object of the further research.

we have made a number of laboratory experiments and analyses which showed that in recovering phosphoric acid from 20 to 40% of the rare earths pass into solution; the remaining 80—60% form a precipitate-—phosphogypsum, replacing calcium in $CaSO_4$* in an isomorphous way.

When we started our investigation, it was generally believed (on the basis of 2—3 analyses) that the rare earths pass into phosphoric acid in too insignificant a quantity to be worth attempts at their handling for practical purposes.

Our analyses of phosphoric acid with varying concentrations and degrees of purity both under laboratory and industrial conditions, showed a content of rare earth oxides from 0.03—0.06 to 0.14%, the content of P_2O_5 varying between 10—11 and 22%, respectively.

The rare earths are well ahead of calcium phosphate in precipitating from phosphoric acid neutralized by some base, and this suggested the idea of step neutralization which would permit under industrial conditions to precipitate the rare earths almost alone at the first step. Aiming at a more complete utilization of the raw material at the working plants of ammonium phosphate and trisodium-phosphate, the authors proceeded to laboratory experiments on step neutralization of phosphoric acid by lime and limestone, ammonia and sodium carbonate.

The phosphoric acid previously freed from fluorine was neutralized with lime milk or limestone, until a content of 70—90% $CaH_4(PO_4)_2$ was established in the solution. 50 to 75% of the rare earth oxides contained in this acid passed thereby into the precipitate. The dry residue contained from 15 to 6% rare earth oxides respectively. The total amount of matter precipitated out of the phosphoric acid during the first step was 0.15—2.0% of the original volume of the acid.

Aside from the rare earth phosphates the precipitate contained calcium sulphate, and small amounts of calcium phosphates, sesquioxides and other admixtures. This precipitate is only a raw product, and the process of obtaining rare earth fluorides from it is by way of its dissolution in hydrochloric acid with further precipitation by fluoric acid. These operations are carried out at rare element plants. Laboratory tests have proved the expedience of concentrating our precipitates by chemical and possibly also by mechanical methods. After solution in hydrochloric acid (weak concentration from the waste of superphosphate production) and precipitation by ammonia, sodium carbonate and NaOH, their concentration amounted to 25% of rare earth oxides. The precipitate is easily filtered and washed. Its decantation from a 22% (after P_2O_5) acid proceeds at a rate of 0.5 m/hour.

The dependence has been established of the degree of precipitation of rare earths upon the concentration of phosphoric acid and the degree of its neutralization. This dependence is brought out in a number of diagrams.

On the basis of laboratory tests the following simple plan may be suggested for producing rare earth concentrates at the working precipitate plants. After having isolated fluorine as silicon fluoride by means of sodium chloride or another alkaline salt, the phosphoric acid is neutralized by $Ca(OH)_2$ up to 80—90% or by $CaCO_3$ up to 70—80% of the first hydrogen atom of H_3PO_4. At the same time rare earth phosphates are precipitated which are then separated from the solution by decantation (or filtration).

Preliminary calculations testify to the economic expedience of this method which promises not anly to satisfy the major part of the country's need in rare earths with comparatively little expenditures, but also to reduce the price of the precipitate.

* Some investigators hold that part of rare earths may be contained in the solid phase as phosphates and fluorides.

Neutralization of the phosphoric acid by ammonia (in ammonium phosphate production) gives better results than neutralization by lime or limestone. The degree of precipitation of rare earths is up to 80—85%; their content in the precipitate is correspondingly up to 24—20%. Practically it is possible to precipitate 100% of the rare earths; this, however, strongly diminishes their concentration in the precipitate (up to 3—5%).

As a result of neutralization of phosphoric acid by sodium carbonate (in sodium phosphate production) the precipitates have a higher content of rare earths (they contain 24%) than in the precipitate production. The degree of rare earth precipitation is up to 75—80%.

As regards the isolation of rare earths from phosphogypsum, the most promising is the suggestion of I. N. Zaozersky (Institute of Rare Elements) to isolate rare earths in the course of producing ammonium sulphate by converting phosphogypsum by an ammonium carbonate solution or gaseous CO_2 and NH_3 according to the well-known reaction*

$$CaSO_4 + (NH_4)_2CO_3 = (NH_4)_2SO_4 + CaCO_3.$$

Then the rare earths pass to a carbonate precipitate from which they may be made to pass into solution by decomposing the precipitate with nitric acid, whereby calcium nitrate is obtained. In order to obtain a concentrate with a higher rare earth content the author suggests mechanical concentration of the residue insoluble in nitric acid. This method may de found in future to be of practical interest; its importance may be limited, however, by conditions under which the working of phosphogypsum to ammonium sulphate and a subsequent working of limy slime to calcium nitrate or the solution of limy slime in hydrochloric acid will be found expedient.

Our laboratory tests of isolating rare earths by decomposing apatite with hydrochloric acid show results closely approaching the results obtained in decomposing with nitric acid (this work is in progress).

Thus, the present state of investigational work enables the problem of a complex utilization of raw material to be solved by means of the decomposition of apatite with nitric, sulphuric and possibly hydrochloric acid, i. e. makes it possible to utilize P_2O_5, CaO, F, TR_2O_3 as well as HNO_3 or H_2SO_4. The utilization of rare earths in superphosphate production and in thermal methods of apatite treatment is a task presenting many technical and economical difficulties.

On the basis of the work carried out by us the methods suggested for the isolation of rare earths from apatite should be tested under industrial conditions and put in practice as soon as possible.

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* The process of converting phosphogypsum to ammonium sulphate has been studied in detail by the scientific workers of the Institute of Fertilizers and Insectofungicides.

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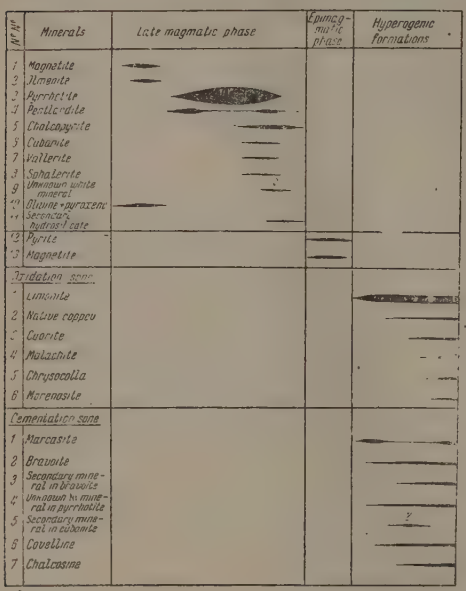
MINERALOGY OF MONCHE-TUNDRA

By I. N. CHIRKOV

(Communicated by A. E. Fersmann, Member of the Academy, 14. VIII. 1939)

The copper-nickel deposits of Monche-Tundra on the Kola Peninsula, though far as yet from being exhaustively prospected, are coming to the fore among the nickel deposits of the Soviet Union by dint of their metal content (nickel, cobalt, copper, etc.) and total ore reserves, being moreover the raw material base of the newly built powerful works «Severnickel». With regard to their genetic peculiarities the deposits of Monche-Tundra appear to have no similar and are therefore of exceptional interest.



The paper presents a description of the mineralogical constitution of the ores of the vein deposits of Monche-Tundra. A diagram is given, showing the succession in which the various minerals were forming as well as their quantitative relation in ores. This is followed by a brief description of the chief rock-forming ore components.

The formation of ore veins within the ore-bearing areas «Nattis» and «Kumuzhia-varaka», related to the differentiation of basic magma, took place during one of the late stages of the magmatic process. No diversity of mineralization phases is observed. In post-ore tectonics, a small part of the ores was subjected to recrystallization with the appearance of new minerals (pyrite, magnetite).

In their mineralogical composition all the veins studied are more or less uniform and are represented by the same complex of ore minerals, of which the chief are pyrrhotite, pentlandite, chalcopyrite and magnetite. Only a not quite uniform spatial distribution of concentrations of some or other ore component within the ore volume is noted. This made it possible to distin-

guish characteristic types, differing from each other by the predominance of one of the chief ore-forming minerals with a subordinate content of the others.

According to the quantitative proportion of the component ore minerals, the following types of ores may be distinguished: chalcopyrite-pentlandite-pyrrhotite ores, the most wide spread ores; then follow the so-called pyrrhotite ores, i. e. low in chalcopyrite and pentlandite; then follow the ores high in chalcopyrite (from 40 to 80%), ores high in magnetite, limonitic and sooty ores. The three last types of ores are of subordinate importance.

When carrying out research work, the main attention was paid to primary ores and to ores which had been subject to dynamic metamorphism. A study was also made of the ores of the oxidized zone and of the zone of secondary sulphide concentration. As a result of investigations, the following series of minerals was established.

Endogene		Exogene	
Mineral	Chem. formula	Mineral	Chem. formula
Magnetite[1, 2]	Fe_3O_4	Limonite	$Fe_2O_3.nH_2O$
Ilmenite	$FeTiO_3$	Native copper	Cu
Pyrrhotite [1]	FeS	Cuprite	Cu_2O
Pentlandite [1, 2]	(FeNi)S	Malachite	$CuCO_3.Cu(OH)_2$
Chalcopyrite [I, II]	$CuFeS_2$	Chrysocolla	$CuSiO_3.nH_2O$
Cubanite	$CuFe_2S_3$	Morenosite	$NiSO_4.7H_2O$
Vallerite	$Cu_2Fe_4S_7$ or	Marcasite[4]	FeS_2
—	$Cu_3Fe_4S_7$*	Melnikovite-pyrite (melnikovite-marcasite)	FeS_2
Sphalerite	ZnS	Bravoite[5]	(Fe, Ni)S_2
Unknown platinum mineral (?)	—	Secondary mineral after bravoite	—
Pyrite	—	Unknown copper mineral after pyrrhotite	—
—	—	Secondary mineral after cubanite	—
—	—	Covellite	—
—	—	Chalcosite	—

The predominating minerals in the ores, in the order of their segregation, are: magnetite constituting up to 10% of the volume of the ore mass; pyrrhotite up to 75%; pentlandite 7—8%, and chalcopyrite 6—7%. The other minerals occur in very insignificant amounts. Separate minerals as shown by mineralographic study were crystallized successively. An idea of this may be formed from the accompanying diagram (p. 126) of age relations of the minerals.

A) In the magmatic phase the first to crystallize out was m a g n e t i t e, often having an euhedral shape of the grains. The grains of magnetite in most cases were subject to corrosion and replacement by sulphides, the latter occur in it as small inclusions. The main generations of magnetite are observed: an ilmenite-containing variety and a variety without ilmenite. The latter prevails. Magnetite tends to occur in the marginal parts of veins, where it

* The chemical formula is given after Scholtz.

gives accumulations in the shape of continuous fine-grained masses, occurring like fringes along the vein walls, or accumulations in these parts of the veins of the largest in size too crystalline phenocrysts. This nature of magnetite accumulations is observed chiefly in the upper horizons of the veins. This is probably because the initial moments of the process of crystallization of the sulphide melt were taking place under prevalence of oxygen.

The second place with regard to the time of the beginning of crystallization and the first place with respect to the quantitative importance in the ores is occupied by p y r r h o t i t e. This mineral was formed as allotriomorphic granual masses. The structures of recrystallization, due to phenomena of dynamic metamorphism, are frequently observed. For pyrrhotite at least two generations are observed. The bulk of it was formed in the earlier stage of crystallization. An insignificant part of it was crystallized later than chalcopyrite and was, most probably, the result of decomposition of the solid chalcopyrite solution.

P e n t l a n d i t e is the third mineral in the order of crystallization from the ore mass. The bulk of pentlandite segregated from the melt simultaneously or after the beginning of recrystallization of pyrrhotite, but a part of it, observed as porphyry-like phenocrysts, had undoubtedly formed previous to the beginning of pyrrhotite crystallization. Moreover, a considerable part of pentlandite segregated from the solid pyrrhotite solution, forming the so-called knitted decomposition structures.

C h a l c o p y r i t e in its main mass segregated after the crystallization of the first three minerals filling the spaces left between the grains of the previously segregated minerals. As a rule, the grains of chalcopyrite possess a complex internal twin structure.

C u b a n i t e is encountered comparatively seldom, forming lamellar bodies in chalcopyrite. It is a typical mineral of decomposition of the solid solution. Closely associated with it is the mineral v a l l e r i t e.

S p h a l e r i t e is observed in ores in insignificant amounts, as small inclusions in chalcopyrite, being likewise a mineral of decomposition of the solid chalcopyrite solution.

A white-coloured mineral with a strong reflecting power has been encountered. Unfortunately, the minute size of the grains of this mineral that were encountered did not permit a precise determination of its composition. Most probably, it belongs to the group of platinum minerals.

B) In the processes of dynamic metamorphism, in connexion with the post-ore tectonics, along with recrystallization, in pyrrhotite masses p y r i t e and m a g n e t i t e of a later generation are formed. The total quantitative importance of these minerals is not great.

C) In the process of weathering of sulphide veins in the zone of oxidation l i m o n i t e is predominantly developed. The limonite ores form gossans of veins and are traceable on the average down to 12—15 m. The composition of limonites has not been sufficiently studied as yet.

Malachite, cuprite, chrysocolla, covellite and chalcocite are encountered in ores of the oxidized zone in small quantities.

D) In the zone of cementation a number of secondary minerals are developed, of which the greatest interest is presented by b r a v o i t e—a secondary mineral after pentlandite. It is rather wide-spread. As a result of the further oxidation of ores, bravoite passes to a secondary mineral of an indefinite chemical composition.

Of the copper secondary minerals, c o v e l l i t e and c h a l c o s i t e have been encountered as well as a secondary mineral of a variable composition, developing after pyrrhotite. It is considerably developed in semi-oxidized

ores, which in the further course of the process of weathering of veins are converted into the so-called sooty ores.

The increasing interest to the copper-nickel ores of Monche-Tundra, with the actual presence in them, in addition to nickel and copper, of a number of valuable elements, such as cobalt, platinum, palladium, selenium, etc., calls forth the necessity of organizing a more detailed study of the mineralogical constitution of the ores and particularly of a detailed characteristic of the principal ore minerals—pyrrhotite, pentlandite and chalcopyrite.

In connexion with the requirements on the part of metallurgists it is exceedingly important to solve the question as to the content of nickel in the pyrrhotites themselves, as well as to know their structural peculiarities and behaviour in the original ores. Therefore one of the immediate objects of the study of the mineralogical constitution of the ores of Monche-Tundra should be a thorough separation of monomineral samples, with the purpose of their full chemical analysis.

In the first place it is necessary to make a more detailed study of the varieties of pyrrhotite, to establish the composition of pentlandite in its different generations, of chalcopyrite and other minerals, using spectral analysis, X-raying and other methods of investigation.

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MINERALOGY

REMAINS OF DIATOM ALGAE IN THE CRYSTALS OF ICELAND-SPAR

By A. G. STANDEL

(Communicated by D. S. Rojdestvensky, Member of the Academy, 2. VII. 1939)

The present work was suggested by the late Prof. A. N. Filippov and was carried out under his guidance in the Spectroscopic Laboratory of D. S. Rojdestvensky. It was close to completion when this laboratory was transferred from the State Optical Institute to the Physical Institute of the Leningrad State University. Its main object was the spectral investigation of the admixture in the coloured calcite of the different layers of the USSR (see the reports of the State Optical Institute for 1938). The crystals from the region of the middle and the lower stream of the river Nijnaya Tunguska* obtained from the Chief Administration of the North Sea Way are of different yellow hue, from a faint lemon yellow up to saturated yellow, and are of special interest possesing besides the mechanical mineral admixtures, the organic ones. Among the latter, it is necessary at present to mention the diatoms which were discovered although not in large quantities, but in a large variety of forms. They were detected accidentally, during an investigation of the mechanical admixtures extracted from the crystals.

In order to extract the mechanical admixtures, 100—150 g of crystals were dissolved in weak hydrochloric acid. The solution obtained was passed through a fine porous glass filter (No. 4 of the works Drujnaya Gorka). The mechanical admixtures and flakes of insoluble substances present in the solution remained on the filter. There they were washed out by reiterated filtration of distilled water, until a complete disappearance in the filtrate of any traces of $CaCl_2$ could be stated by means of a reaction with $AgNO_3$. Then the thin residual layer of the last portion of water on the filter was agitated and with the admixture suspended in it transferred into a test-tube, where the admixture settled completely. Using a pipette it was possible to remove nearly all the water over the sediment and a sample of the latter was taken on microscope slides. After it was dried there, attempts were made to dissolve it by different organic and mineral solvents. Among the former ethyl alcohol, benzine, benzene, carbon bisulphide, toluene, acetone, sulphuric ether were used; among the mineral solvents, the diluted and the concentrated hydrochlo-

* The crystals we were able to obtain appeared to be taken from the following two places: 68 km from the mouth up the river Nijnaya Tunguska and near the issue of the river Keramki. Unfortunately, they were not separated when handed over to us. Keramki is a small affluent of the Nijnaya Tunguska, the distance between these two places appeared to have been about 500 km (see the map of the Turuhansky district, published by the Krasnoyarsk Committee of Assistance to the Nationalities of the North).

ric, nitric and sulphuric acids. The effect of all but two latter solvents was only to wash out the yellow pigment and discolour the admixture. In the case of concentrated nitric and sulphuric acids, however, which had dissolved some of the particles, among the undissolved mineral particles of the admixture there were found fragments of siliceous shells of the diatoms. Some of the shells were quite intact. In Fig. 1 a photomicrograph of the mechanical admixture extracted from a crystal and treated by the nitric and the sulphuric acid is given. Among the mineral particles one may see there an intact diatom of the *Rhopalodia* family. In Fig. 2 another diatom of the *Navicula* family, surrounded by diatomic fragments, is seen.

The diatoms being wide spread, it was necessary to take into consideration the possibility of their presence on the walls of the vessel, in the dust of the

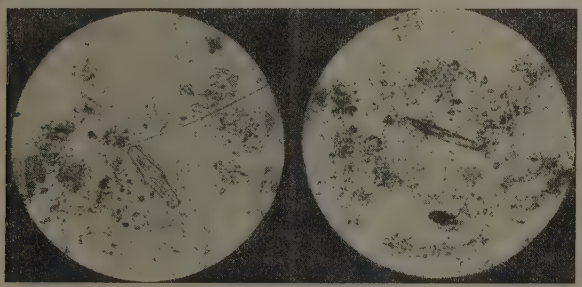

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 1. A photomicrograph of the mechanical admixture, extracted from the crystals and treated by nitric and sulphuric acids. Magnification 310.

Fig. 2. The same as Fig. 1.

Fig. 3. A photomicrograph of a section of a crystal. Magnification 175.

air, and their accidental getting into the distilled water which had been used for washing out the admixture. Accordingly, a check experiment was indispensable. For this purpose the filter had been most carefully washed and a double bulk of distilled water, compared to that previously used, was passed throughout the same vessel. Just as before the agitated last portion of water, quite transparent now, was poured out from the filter into the test-tube. Placed by means of a pipette on the microscope slide and dried there, the remains were examined under the microscope. Against a background of an insignficant quantity of mineral admixture, nothing was observed, except some filaments, evidently of a dust origin.

Being unsatisfied with this test, we rubbed the walls and bottom of the bottle which had contained the distilled water with cotton wool inside. Some gigantic species of diatoms of *Gyrosigma* family were detected in the smears from this cotton. And if nothing like the diatoms of the mechanical admixture of the crystals could be detected in those smears on most careful examination, nevertheless there arose certain doubts about the results of the previous investigation in view of the insufficient cleanness of the vessel. It was indispensable to repeat the experiment.

When a new portion of crystals was dissolved, not only fresh water was used in washing, but due care was taken also with regard to the crystals themselves. Each crystal was thoroughly examined for the absence of splits and the cleanness of its surface; the suspicious places were cleared off. Previous to solution, the surface of the crystals was etched by immersion into hydro-

chloric acid for 1—2 min.; afterwards they were washed with water. Dust was kept away from the vessel. The result was the same as in the first case, that is to say, there were found in the admixture diatoms intact and in fragments, nearly in the same quantity and of the same forms. Later on, dissolution of single crystals was performed and it was found that not all of them contained diatoms.

It was natural to look under the microscope for diatoms directly in the crystals. For this purpose, thin plates of crystals were chosen. These were placed on the object table of the microscope and examined in different planes of optical section. It stands to reason that minute separate particles which might occur in the field of vision could not possibly be examined in detail, since the thickness of the crystal plates prevented the use of a high magnifying power. Now was it to be expected that the structure of diatoms could be observed in detail, inside the crystals, as it is the case with the purified specimens treated with acids. In this preliminary work it was known a priori that the structure of the valves remains inobservable, but should particles resembling the diatoms by their dimensions and appearance be detected in the crystals this could be a confirmation of the results obtained previously. The problem was complicated by the fact that the quantity of diatoms in crystals is rather inconsiderable. Only some intact small diatoms (we did not come here across any big forms of them) were extracted by dissolving large amounts of crystals (100—150 g).

Nevertheless, the examination directly in the crystals was a success. In some of them particles were observed in the field of view which were very suggestive of diatoms by their outward appearance as well as by their dimensions. In Fig. 3 a photomicrograph of a section of a crystal is given; in the upper part double outlines (because of the double refraction in crystals) of two small bodies, reminiscent of diatoms, are visible*. From their dimensions, form, axial field, yellowish hue, the presence of air bubbles within them, we arrive at the assumption—though the main criterium, the visible structure of valves, is absent—that we have here to deal with diatoms.

The following circumstance must now be pointed out. In some crystals, besides the bodies mentioned above, the spiculae of sponges and some discoloured, transparent filaments were observed. The thickness of these filaments varies from some tenths of a micron up to 10 microns and even more. Their length varies from a score or two of microns up to one centimeter and more. At least some of the largest filaments have a cavity (the axial canal) inside them with the remnants of the contents. The filaments are distinctly visible in the crystal even to a naked eye. Extracted from the crystal they refused to dissolve in concentrated nitric and sulphuric acids and withstood calcination in a crucible at 800—900°, being bent but not destroyed by this treatment. In Fig. 1 these filaments magnified 310 are seen alongside of the diatoms. When the crystals with filaments were dissolved, the diatoms were found in the admixture, but no diatoms were found in the admixture from the crystals containing no filaments. In the case of direct microscopic examination too small bodies resembling the diatoms by their form and dimensions were observed only in the crystals containing filaments.

The examination of these bodies proves that they are located amidst the homogeneous mass of the crystal and are not to be found in the splits or nonuniformities. Consequently, they get into the crystal during its formation and their presence there cannot be ascribed to any secondary process. The diatoms found in the admixture extracted from the crystals may be referred to the families: *Amphora*, *Cymbella*, *Navicula*, *Rhopalodia*, *Fragilaria*,

* It is the unpolished sides of the crystal which are largely responsible for the stains and lines seen on the photograph.

Tabellaria and others. Their detailed specification has been undertaken by V. E. Kozlov, biologist of the State Optical Institute. We would like to thank him for many valuable advices during the progress of this work.

The manuscript of this paper was revised by M. D. Zalessky, W. S. Poretsky, and many valuable remarks were made by them.

If further investigation of diatoms in the calcite is of interest, it may be carried out much better and more definitely than it was done in our short work.

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STRATIGRAPHY

RÔLE OF THE *RUGOSA* AND *TABULATA* CORALS IN THE STRATIGRAPHY OF THE LOWER CARBONIFEROUS OF THE MOSCOW BASIN (NORTHERN PART)

By B. S. SOKOLOV

(Communicated by A. A. Borissiak, Member of the Academy, 7. VIII. 1939)

The paper presents a concise survey of new data on the study of the *Rugosa* and *Tabulata* corals and their rôle in the stratigraphy of the Lower Carboniferous of the northern part of the Moscow basin. Since in the northern part I have accepted the stratigraphical scheme developed by M. S. Shvetzov for the southern part, the conclusions made may be applicable also to the whole Moscow basin.

The Lower Carboniferous deposits of the northern part of the Moscow basin begin with an areno-argillaceous series C_1^{tN}, lying on the surface of the eroded Devonian D_3^{2-1}. This series from the south to the north successively comprises the coal-bearing and Tula beds (Borovichi-Lyubytino region), the coal-bearing, Tula, Alexin beds (Tikhvin region), the Tula, Alexin, Mikhailov beds (Andom region).

Thus, the marine fauna appears not everywhere simultaneously, and the first corals refer essentially to the lower portion of the Alexin beds.

Okian series

Alexin beds $C_1^{ok.al.}$. Including into these beds the first limestone of the Borovichi-Lyubytino region which still has in its fauna Tula elements, we obtain the following list of coral fauna, characteristic of the Alexin beds (up to a_5 of the Msta section):

Chaetetipora confluens Struve
Chaetetipora cirrata Sok. (sp. n.)
Chaetetes septosus Flem.
Syringopora ramulosa Goldf.
Syringopora reticulata Goldf.
Syringopora gigantea Thoms.
Syringopora lata Phill.
Syringopora conferta Keys.
Syringopora gracilis Keys.
Syringopora rossica Stuck.
Syringopora repens Stuck.
Syringopora catenata Mart.
Syringopora geniculata Phill.
Lithostrotion junceum Flem. var. α Perna
Lithostrotion junceum Flem. var. β Perna
Lithostrotion caespitosum Mart.
Lithostrotion irregulare Phill.
Lithostrotion mccoyanum E. H.
Aulophyllum (*Cyclophyllum*) *mstensis* Stuck.
Palaeosmilia murchisoni E. H. (abundance)
Dibunophyllum turbinatum M'Coy
Carcinophyllum vaughani Salee
Koninckophyllum interruptum Thoms. et Nich.
Campophyllum sp.
Orionastraea (2 species)
Caninia (a new, very peculiar group)

Mikhailov beds—$C_1^{ok.mkh}$. In these beds for the first time appear *Lonsdaleia*. The coral fauna has numerous representatives, is variable and markedly different from the Alexin fauna. Corresponds to 5—7 limestones of the Msta river.

Chaetetes capillaris (Phill.)
Chaetetes septosus Flem.
Chaetetes septosus Flem. var. *lepas* Sok.
Chaetetes boswelli Her.
Chaetetella filiformis Sok. (sp. n.)
Chaetetipora sp.
Syringopora ramulosa Goldf.
Syringopora hoffmanni Stuck.
Syringopora distans Fisch.
Syringopora lata Phill.
Syringopora regularis Sok. (sp. n.)
Lithostrotion rossicum Stuck. (abundance)
Lithostrotion irregulare Phill.
Lithostrotion janischewskii Sok. (sp. n.)
Lonsdaleia bronni E. H.
Lonsdaleia duplicata Mart. (rarely)
Lonsdaleia floriformis Flem.
Campophyllum caninoides Silly
Koninckophyllum proliferum Thoms. et Nich.
Palaeosmilia murchisoni E. H.
Aulophyllum fungites Flem.
Dibunophyllum turbinatum M'Coy
Dibunophyllum pseudoturbinatum Stuck.
Caninia scornuta Stuck.

Venev beds $C_1^{ok.ven}$ (=a_8 of the Msta section and the corresponding horizon in the north, previously assumed as the *b* beds). The most characteristic peculiarity of the coral fauna of these beds is the wide distribution of lamellar *Chaetetida* of the group *Ch. crustaceus*. The fauna is as follows:

Chaetetes septosus Flem.
Chaetetes boswelli Her.
Chaetetipora tulensis Struve
Chaetetipora elongata Struve
Ch. (*Chaetetiporella*) *crustacea* Sok. (sp. n.)
Ch. (*Chaetetiporella*) *repens* Sok. (sp. n.)
Ch. (*Chaetetiporella*) *conicellata* (sp. n.
Syringopora reticulata Goldf.
Syringopora ramulosa Goldf.
Lonsdaleia floriformis Flem.
Lonsdaleia floriformis crassiconus M'Coy
Lonsdaleia bronni E. H.
Palaeosmilia murchisoni E. H.
Palaeosmilia stutchburyi E. H.
Dibunophyllum vaughani Salee
Dibunophyllum vaughani Salee var. *densum* Salee
Dibunophyllum turbinatum M'Coy
Dibunophyllum vermiculare Stuck.
Dibunophyllum bristolense G. G.
Corwenia rugosa (M'Coy)
Lithostrotion mccoyanum E. H.
Lithostrotion irregulare Phill.
Campophyllum amplexoides Stuck.
Aulophyllum (*Cyclophyllum*) *zitteli* Stuck.
Koninckophyllum proprium Sibly?
Caninia juddi Thoms.

It is very characteristic that the abundant and diverse fauna of single *Rugosa*, typical of the Venev beds, does scarcely if at all enter the Serpukhovian series. The latter is distinguished by a sharp decrease of single *Rugosa* corals, a wide distribution of the genus *Lonsdaleia* and the luxuriant development of the genus *Chaetetis* (s. str.) of the spherical type.

Serpukhovian series

Tarussa beds (=the Rovno limestone=*b*)—$C_1^{srp.t.}$. The coral fauna of these beds is characterized by the prevalence of *Chaetetida* and *Lonsdaleia*, is not everywhere equally wide developed and is a more deep-water one than the fauna of the Venev beds. The list is as follows:

Chaetetes janischewskii Sok. (sp. n.)
Chaetetes tenuiradiatus Sok. (sp. n.)
Chaetetes septosus Flem.
Chaetetes rossicus Sok. (sp. n.)
Chaetetes tabulicarens Sok. (sp. n.)
Chaetetes scaphoideus Sok. (sp. n.)
Chaetetes capillaris (Phill.)
Chaetetella depressa (Flem.)
Chaetetipora textilis Sok. (sp. n.)
Chaetetipora elongata Struve
Chaetetipora arbustiformis Sok. (sp. n.)
Syringopora distans Fisch.
Syringopora ramulosa Goldf.
Syringopora regularis Sok. (sp. n.)
Lonsdaleia floriformis Flem. (some var.)
Lonsdaleia papillata E. H.
Lonsdaleia papillata E. H. var. *minor* Sok. (v. n.)
Diphyphyllum siphonodendroniformis Sok. (sp. n.)
Caninia struvii Stuck.

Steshevo beds (=probably to the whole thickness of beds *c*) $C_1^{srp.st}$. The upper boundary of these beds is drawn by me, as well as in the

southern part of the basin, from the appearance of *Gigantella latissima* Sow. var. *typica* Sar. and *Gigantella edelburgensis* Phill. The coral fauna is quantitatively reduced, but its habitus remains the same. These beds include 10—23 limestones of the Msta river. The following species are characteristic:

Chaetetes rossicus Sok. (sp. n.)
Chaetetes tenuiradiatus Sok. (sp. n.)
Chaetetella tenuistriata Sok. (sp. n.)
Syringopora reticulata Goldf.
Syringopora distans Fisch. var.
Cladochonus crassus M'Coy
Lonsdaleia floriformis Flem. *c* var.
Lonsdaleia papillata E. H.
Lonsdaleia annulata Stuck.
Lithostrotion portlocki E. H.
Koninckophyllum proprium Sibly
Orionastraea ex gr. *edmondsi* Hudson
Campophyllum amplexoides Stuck.
Cyathaxonia sp.
Palaeosmilia sp.

Protva beds (=«the Uglov horizon»+upper limestones of the Msta section=*d*). The brachiopod and coral fauna of these beds is distinguished by the presence of many new forms. The following are characterized:

Chaetetes rossicus var. *superior* Sok.
Chaetetes gracilis Sok. (sp. n.)
Chaetetes lungtanensis Lee et Chu
Chaetetes pinnatus Sok. (sp. n.) (abundance)
Cladochonus sp.
Syringopora reticulata Goldf.
Lonsdaleia floriformis Flem. *c* var.
Lonsdaleia duplicata Mart.
Lonsdaleia papillata E. H. var.
Palaeosmilia regia Phill.
Dibunophyllum sp. n.
Lophophyllum sp. n.

The list of fauna enumerated is far from exhausting the diversity of the Lower Carboniferous corals of the northern part of the Moscow basin, but the above list, including about 100 species, reflects with sufficient clearness the stratigraphic significance of this fauna.

The study of the coral fauna fully confirms the correctness of the stratigraphy adopted for the Moscow basin and the complexes of species established very clearly characterize all the subdivisions of the deposits studied. In this connexion it would be very interesting to draw a parallel with the zonal subdivision of the Lower Carboniferous deposits of England. This comparison has not been so far carried out to a satisfactory extent, since the coral fauna laid at the base of the stratigraphs of the Lower Carboniferous of England, in the Moscow basin became the subject of study only in the last few years.

The first attempt to correlate the deposits discussed with those of England was made in 1935 by M. V. Karaeva, who referred the Okian series to the subzone D_1, and the Serpukhovian, to D_2. My investigations, based on a considerably more complete and diverse material, have brought me to somewhat different conclusions.

All the Lower Carboniferous deposits of the northern part of the Moscow basin are referred to the Visean, the underlying areno-argillaceous beds C_1^{bN} to a considerable extent referring to the upper portion of the *Seminula* zone (up to the middle of the Tula beds), and the higher lying deposits up to the base of the Protva beds, to the *Dibunophyllum* zone.

Referred to the D_1 subzone should be the upper portion of the Tula beds, the whole of the Alexin and, possibly, the lowest portion of the Mikhailov beds. In the northern part this subzone is characterized by an exceedingly wide spreading of *Palaeosmilia murchisoni* E. H., an abundance of various *Syringopora* and *Lithostrotion junceum* Flem. *c* var. and *caespitosum* Mart.

Referred to the D_2 subzone should be the Mikhailov beds, in which appear first *Lonsdaleia floriformis* Flem., and the Venev beds, where they have a luxuriant development. Both the former and the latter beds are characterized by a luxuriant development of single *Rugosa*, various *Dibunophyllum*, *Aulophyllum fungites* Flem. *c* var., *Koninckophyllum*, *Caninia juddi* Thoms., *Corwenia rugosa* (M'Coy), *Lithostrotion rossicum* Stuck., *irregulare* Phill.

and a peculiar group of lamellar *Chaetetidae* and with meandric cells. This group is spread also in the D_2 subzone of England.

The fauna of the Serpukhovian series is exceedingly different from the Okian by the reduction of the simple *Rugosa*, a considerable renovation of *Chaetetida* and a peculiar fauna of small *Productidae*, on the base of which Lisitzyn, as early as in 1911, correlated the Serpukhovian deposits with the D_3 subzone of England. The coral fauna, while being markedly different from the English one, does not seem to me to be conflicting to this correlation. Thus, to the D_3 subzone may be referred the Tarussa and the Steshevo beds until the next sharp renovation of fauna from the Protva beds. The most characteristic of it is the flourishing of the genus *Chaetetes* (s. str.)—the species *rossicus* Sok., *tenuiradiatus* Sok. etc., *Chaetetipora textilis* Sok., as well as the appearance of *Lonsdaleia papillata* E. H., *Cyathaxonia*, *Cladochonus crassus* M'Coy. Single *Rugosa*, with the exception of *Caninia* (locally) and *Campophyllum amplexoides* Stuck., almost lose any significance.

From the Protva horizon the fauna of corals, as well as that of brachiopods, suffer the next renovation of their forms and cannot be confined within the boundaries of the *Dibunophyllum* zone. This fauna I refer to the Namurian. It is distinguished by the predominance of peculiar *Chaetetida*, of which *Chaetetes lungtanensis* Lee et Chu, *Chaetetes pinnatus* Sok. already tend to the Middle Carboniferous. The *Rugosa* fauna is also peculiar.

The correlation of the Lower Carboniferous deposits of the northern part of the Moscow basin with the classical section of the Lower Carboniferous of England shows that the accepted subdivision of the Lower Carboniferous deposits of the Moscow basin, well-founded on the consideration of both the brachiopod and the coral fauna, is to a considerable extent more detailed than the zonal subdivision of the Carboniferous of England, and the Carboniferous of the Moscow basin in this respect will surely become a stratigraphic standard not only for the USSR, but for Western Europe as well. A valuable contribution to it will be the study of the corals of the southern part of the Moscow basin.

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BIOLOGY

DISTRIBUTION AND DYNAMICS OF LIVING MATTER IN THE CASPIAN SEA

By S. W. BRUJEWICZ

(Communicated by S. A. Zernov, Member of the Academy, 29. VII. 1939)

The study of dynamics of the biogenous elements in the sea involves quantitative investigation of the distribution of living matter there among the major groups of living organisms—bacteria, plankton, benthos, nekton—as well as estimation of its «turnover» in terms of the P/B coefficient (relation of production to biomass) for each group separately. The biological study of the Caspian Sea has made at present such progress, that we are able at this juncture, first, to give a general outline of the distribution of living matter among the major groups of marine hydrobionts, i. e. to show their biomasses, and secondly, to trace the rates of the building up and breaking down processes by referring to the production of this various groups in bulk. What is meant by the production in bulk is the total amount of living matter produced by a given group of organisms for a given period of time, i r r e s p e c t i v e o f t h e f u t u r e d e s t i n y o f t h e c r e a t e d o r g a n i s m s. We are giving below data on biomasses and P/B coefficients as well as on the chemical composition for the principal hybrobiont groups of the Caspian Sea.

B a c t e r i a. The total number of bacteria in the Caspian Sea was estimated by E. V. Dianova and A. A. Voroshilova whose works have been published but in part ([1,3]). Determinations were made by direct microscopic counting of bacteria detained by a membrane ultrafilter from 50—100 cm³ of sea water. The average size of a bacteria according to Dianova and Voroshilova is 1 cub. micron. Taking this for granted and assuming that the average number of bacteria is 100 000 per 1 cm³ water, we will get a figure of 8 million tons for the total wet weight of bacteria in the Caspian Sea. It should be noted here that the bacterial population of the sea grounds has not entered into this calculation for want of more or less trustworthy data. The ratio of dry matter in bacteria is 20—25% according to Furman. The average humidity was accepted by us to be equal to 80%. The mean chemical composition of bacteria was supposed to accord with the data published by Fedorov ([6]).

The task of determining the bacterial production is much more involved. Our count was based on the following considerations. As shown by Voroshilova and Dianova ([1]), the increase of accumulation of bacteria in boiled or ultrafiltered water should be explained first of all by the elimination of the zooplankton feeding on bacteria. The same reason accounts for the accumulation of bacteria in isolated samples of natural waters. According to Voroshilova and Dianova, the increase in the t o t a l n u m b e r of bacteria, as calculated by direct count on ultrafilter, is under these conditions 1.6—4.5 times for the first 24 hours, being on 3 times a day the average. We are there-

fore entitled to assume that the total daily production of bacteria, provided they are not consumed by zooplankton, would be, roughly speaking, about 3 initial biomasses (at $\sim 20°$). All we know on the rate of multiplication of bacteria under natural conditions is the unpublished data of M. A. Kastalskaya, referring to the water pockets of the river Malaya Istra. The number of daily divisions was 2.1 at 18°C, 0.8 at 12°C and 0.2 at 5.2°C. Thus, the bacteria production in the M. Istra river constitutes about 2/3 of the production of the Caspian. We accept for the Caspian with its 3/4 by volume maintaining a temperature of 5—7° throughout the year, a mean value of P/B equal to 0.7 in 24 hours. Hence the mean annual P/B coefficient equals $0.7 \times 365 = \sim 250$. Naturally enough, this figure is a very rough estimate and at best indicates nothing but the order of turnover value for the living matter of bacteria in the magnitude of sea. The P/B coefficient for bacteria, lower as compared to that of phytoplankton, is accounted for by the fact that the former refers to a considerably higher temperature of the superficial heated layer.

P h y t o p l a n k t o n. According to P. I. Usachev (VNIRO) the total biomass of phytoplankton for the whole Caspian Sea amounted within the period August-October 1934 to a wet weight of about 3 500 000 tons. The biomass was determined by the precipitation method for each species separately. Within the period August-October 1934 the phytoplankton in the Caspian Sea was found to consist of: diatomaceae 47%, *Exuviella cordata*—33%, blue-green (algae)—6%, miscellaneous—14%. The content of nitrogen and phosphorus in the plankton was determined from the unpublished data on the chemical composition of the plankton summarized by A. P. Vinogradov. In June-August 1936 the total wet weight of phytoplankton calculated on the basis of Usachev's data amounted already to about 11 million tons. To a very great extent this tremendous increase occurred at the expense of the enormous development of *Rhizosolenia calcar-avis*. Such are the extremely great fluctuations in the sea's wealth of life within as basic a group of marine organisms as phytoplankton. The daily «turnover»—P/B coefficient for phytoplankton, according to our former determinations of the phytoplankton production from the daily fluctuations of oxygen, may roughly be estimated as 1.5 or the annual coefficient about 300 (taking the production of 200 summer days for the annual total).

Z o o p l a n k t o n. Data on the biomass of zooplankton after V. A. Yashnov (VNIRO). The total of zooplankton, according to this author, for the period August-October 1934 amounted to about 5 million tons of wet weight. The content of dry matter in zooplankton is taken by us to amount to 10% of wet weight. Data of the chemical analysis are quoted by us from Vinogradov's list. We are not in possession of sufficiently reliable data to calculate the P/B coefficient for zooplankton. A. V. Okul has determined the annual production for the Azov Sea from monthly observations on the change of the biomass making allowance for the amount consumed by plankton-eating fish. The P/B coefficient for *Copepoda* was found by him to amount to 30. The actual coefficient should be much higher, since natural dying off was not taken into account. But no data on the Caspian Sea were available, and considering the high relative value of *Copepoda* in zooplankton in general, we accepted this coefficient for the zooplankton of the Caspian as well.

Z o o b e n t h o s. The figures for the total amount of benthos are borrowed from the unpublished data by J. A. Birstein, based on the observations by M. M. Briskina, D. Z. Demina and Birstein himself (VNIRO). Roughly speaking, the biomass of benthos up to 1935 constituted 30 million tons of wet weight. The average content of dry matter in the moist zoobenthos is

assumed by us to amount to 15% by weight; the data on chemical composition are as summarized by Vinogradov. As further investigations have revealed, the life bulk of benthos may, at least for separate regions of the sea, show enormous annual fluctuations. According to A. A. Shorigin, the P/B coefficient for zoobenthos may be assumed to equal 4 on the average.

Phytobenthos. The total amount of moist phytobenthos in the Caspian Sea, principally of *Chara Characeae* and *Zostera nana*, may, according to the rather rough estimate by M. S. Kireeva and T. F. Schapova (VNIRO), be assumed to amount to 3 million tons. The dry weight is approximately 8 times less. Chemical compositions, according to Vinogradov ([2]). The annual P/B coefficient for the Caspian as a whole may be taken, according to Kireeva and Schapova, to be equal 1.

Fish. The total amount of fish in the Caspian Sea may be estimated but very roughly on the basis of the following data. The average catch of fish in 1934—37 was about 450 000 tons. Assuming the annual capture to make nearly one third of the total amount of marketable adult fish available in the sea, on which figure most of the ichthyologists agree, we derive a figure of about 1.5 million tons for this sea's wealth of marketable adult fish. The weight of the young of marketable fish is roughly estimated by us to be equal to the weight of marketable adult fish. Thus, the total amount of commercial fish in the Caspian is tentatively assumed to have been about 3 million tons for the period 1934—36. The total of sprats thriving in prodigious numbers throughout the entire Caspian is not likely to be figured with any degree of certainty, since the capture of sprats is in no way indicative of the actual wealth of this fish in the sea. Assuming the number of sprats together with gobies, the latter not being mirrored in catches either, to be equivalent to the amount of marketable fish, we roughly obtain a total of 6 million tons for the bulk of fish in the Caspian. The data on the chemical composition of marketable fish of the Caspian accepted by us are those given by M. P. Osipov([4]).

Table 1

	Biomass					Annual coefficient P/B	Annual production		
	Wet weight	Dry weight	% of dry weight	Nitrogen	Phosphorus		Wet weight	Dry weight	% of dry weight
Bacteria, 1935 . . .	8 000	1 600	18	200	20	250	2 000 000	400 000	75.0
Phytoplankton, 1934.	3 500	350	3.8	13.2	2.24	300	1 000 000	100 000	18.7
Zooplankton, 1934 . .	5 000	500	5	50	5	30	150 000	15 000	2.8
Zoobenthos, 1935 . .	30 000	4 500	49	450	45	4	1 200 000	18 000	3.3
Phytobenthos, 1935 .	3 000	375	4	6	0.7	1	3 000	375	1.07
Fish, 1934—36 . . .	6 000	1 800	20	170	21	0.5	3 000	900	0.16
Marine animals . . .	70	21	0.2	2.1	0.24	0.35	25	7	0.001
Total	55 600	9 150	100	891	94	—	—	—	100
Annual catch of fish 1934—37	450	130	—	13	1.6	—	—	—	—
Phytoplankton, 1936 .	1 000	1 100	—	—	—	—	—	—	—

Seals. According to the data of S. J. Freiman (VNIRO), the Caspian school of seals is estimated to comprise about 1—3 million animals. We accept

an average of 2 million specimens with an average spring weight of 35 kg each, making a total of 70 000 tons raw weight. The annual coefficient for seals, according to Freiman, equals to 0.35.

The bulk and production of separate groups of hydrobionts in the Caspian in terms of both wet and dry weight and the data on nitrogen and phosphorus content (in thous. tons) are given in Table 1. On the dry weight basis the relation between the biomasses of zoobenthos, fish, zooplankton and phytoplankton is 2.5 : 1 : 0.25 : 0.2, respectively. Assuming very roughly that plankton-eating fish (mainly, sprats) consititute one half of the entire biomass of fish, we derive the ratio of the biomass of plankton-eating fish to zooplankton and phytoplankton as 1 : 0.5 : 0.4. The relation of zoobenthos to fish both benthophagous and predacious may be expressed, very roughly, as 5 : 1. Considering that half of the biomass of benthophagous fish are taken up by young and that part of the latter feed on plankton, the actual ratio of benthos and fish is higher than 5 : 1. The fact that the biomasses decrease in the order fish, zooplankton and phytoplankton is easily explained in terms of the annual production which is decreasing in the reverse order (Table 2).

Table 2

Annual Production without Bacteria

	in thous. tons	in %
Phytoplankton	100 000	75
Zoobenthos	18 000	13
Zooplankton	15 000	11
Fish	900	0.7
Phytobenthos	375	0.3
Marine animals	7	0.005
Total	134 300	100.0

A fish haul of 450 000 tons raw weight constitutes about 1.4% of the total living matter in sea (dry weight). With the removal of this amount of fish the sea loses 13 000 tons of nitrogen and 1600 tons of phosphorus. This amount constitutes about 2.6% of the whole of mineral nitrogen and 3.6% of the entire mineral phosphorus in the upper 50-meter zone of the Caspian Sea. If we assume roughly that the North Caspian yields three quarters of the total catch of fish, the nitrogen of the annual catch of fish in the North Caspian constitutes about 28% of the whole of mineral nitrogen, and the phosphorus of the catch—about 18% of the total amount of phosphorus of the North Caspian.

These figures show that if the elimination of biogenous elements with the fish presents a negligible quantity in relation to the wealth of easily available matter in the upper 50-meter productive zone of the Caspian, nevertheless the value becomes appreciable if considered in relation to the North Caspian alone.

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GENETICS

COMPARATIVE MORPHOLOGY OF THE CHROMOSOMES IN WHEAT

By G. A. LEVITSKY, Corresponding Member of the Academy,
M. A. SIZOVA and V. A. PODDUBNAJA-ARNOLDI

Wheat species offer a classical example of multiple or so-called «polyploid» chromosome numbers. The einkorn group possesses 7 chromosome pairs, hard wheats—14, soft wheats—21. Presence in reduction division of pairs of chromosomes belonging to different species, when these chromosomes are combined in the hybrid nuclei, testifies both to genetic compatibility or «homology» of individual chromosome type and to identity or similarity of their structure as shown by morphology of somatic chromosomes. The degree of uniformity and completeness of the union of the chromosomes forming «bivalents» would determine the degree of their morphological similarity. All the students of hybrids between the soft wheats and the common species of hard wheats have established a nearly constant presence of 14 bivalents and, besides, mainly of the so-called «closed» type (at both ends) ([1],[2]). On the basis of these facts it is assumed that the 14-chromosome set of the hard wheats composed of two «genomes» consisting of seven chromosomes each is wholly and rather exactly represented in the 21-chromosome set of the soft wheats in the *Y* and *B* genomes possessed both by the hard and soft wheats. The latter possess in addition the *D*-set containing again seven chromosomes.

Hybrids between hard wheats and einkorn, although they show less regular and stable relations (the number of pairs varies here even in one and the same anther), nevertheless in the majority of cases form 5—6 and even 7 bivalents; in some cases there were as many as 5 of them of the «closed» type ([1]). All the above said leads to the conviction that the 7-chromosome set of the einkorn group corresponds to a great extent to the one of the genomes of the hard and soft wheats which was conventially designated by *A*.

The above-noted chromosome relations at reduction division induced us to a study of the chromosomes of wheat at somatic division where it was hoped to distinguish their individual types on the basis of their relative sizes, of their primary differentiation and of their secondary subdivision of the arms, in order to compare subsequently these types in different wheat species and thus to work out a morphological characteristic of the three «genomes» of wheat.

In the present communication are contained data relating to three species which belong to three sections of the polyploid series of wheat: *Triticum monococcum* (v. *Hornemanni* Clem.), *Tr. polonicum* and *Tr. vulgare* (v. *erythrospermum* Körn.). These data are based on the study in each of these species of the chromosomes belonging to the one and the same chromosome plate

arranged in a most favourable manner (Fig. 1, *A*, *B*, *C*) and carefully measured with the aid of the «projection method» as worked out by us (3)*.

To make clear the differentiation of the chromosomes, there was used the fixation with a mixture of platinum chloride with formalin («strong» formula) as introduced by us (4) and ordinary staining with iron haematoxylin. Prior to fixation the seedlings were subjected to cold by placing them on ice for 24 hours in order to straighten the chromosomes. As a certain shortening of the chromosomes which took place after this was not quite equal in different portions of material, all the sizes of the chromosomes of *Tr. vulgare* (which were somewhat stronger shortened in the plate measured) were increased by one tenth for the sake of expedience of comparison. The results of our analysis are represented by figures and idiograms (Fig. 2). The latter were prepared on the basis of selection of chromosomes which proved to be the most similar in the species investigated.

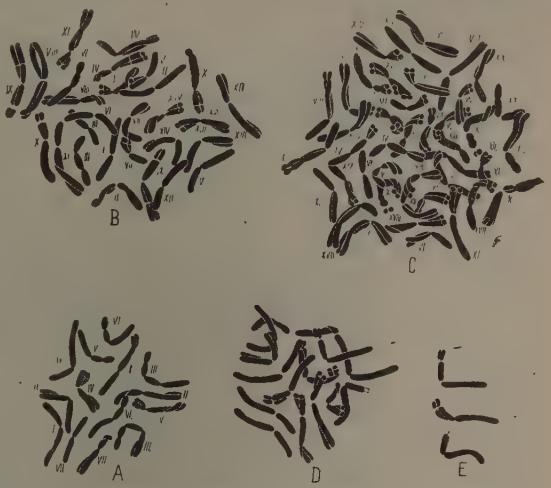

Fig. 1. Nuclear plates: *A*—*Triticum monococcum*, *B*—*Tr. polonicum*, *C*—*Tr. vulgare*, *D*—*Tr. aegilopoides* possessing each two chromosomes with «appendices»; *E*—chromosomes with «appendices» and with «satellites» drawn separately.

In *Tr. polonicum* and *Tr. vulgare* first attention is attracted by chromosomes possessing the so-called «appendices isolated by achromatic constriction». Such peculiar chromosomes were described by us (5,3) in rye and barley and by Senianinova-Korchagina (6) in species of *Aegilops*. In wheat they were first exactly established by V. A. Poddubnaja-Arnoldi in *Tr. durum* represented by two pairs as well as in *Tr. vulgare***.

Recently, again from our laboratory, there came a communication (9) on the connexion between these chromosomes and the nucleolus. The «appendices» are connected with the body of the chromosome with threads (M. V. Favorsky, in rye, unpublished) which usually are not stained at all. Complete absence of chromosomes of this type in the einkorn group is remarkable, as shown by M. A. Sizova in all the three species. «Nuclear» chromosomes are represented here by chromosomes (IV) with typical extremely small satellites suspended on threads. These chromosomes very much differ also in their relative dimensions and ratio of arms from the chromosomes with appendices possessed by *Tr. polonicum* and *Tr. vulgare*. In the latter two species the two pairs of chromosomes with appendices are extremely similar***. Aside

* *Tr. monococcum* and *Tr. polonicum* were measured by M. A. Sizova, *Tr. vulgare* by I. P. Vassilieva. The measurements were checked and in part corrected by G. A. Levitsky.

** Kagawa (7) does not discriminate between our «appendices» and ordinary partitions or «heads» of the chromosomes (see his text figures 7, 9 and 11). «Fragments» described by D. Kostoff (8) in wheat hybrids probably present again our «appendices».

*** This similarity becomes especially clear when one considers only stained chromosome portions and disregards the highly variable «achromatic interval», i. e. essentially the «thread» of the appendix.

from the described «interval» it was possible in many cases to establish in certain chromosomes the so-called secondary constrictions. It is found to be of great constancy in the III and IV chromosomes in the einkorn group. As to other wheat species, the secondary constrictions are far from being always clear irrespective of the strength of differentiation of the slide, although they are fixed at definite points of definite chromosomes, just as described earlier by Kagawa (7). This probably is a feature peculiar to differentiation of the inner layer of the chromosome sheath as contrasted to constant differentiation of the whole its thickness, as it is the case, for example, in the threads of the «genuine» satellites and appendices. In any event this unstable

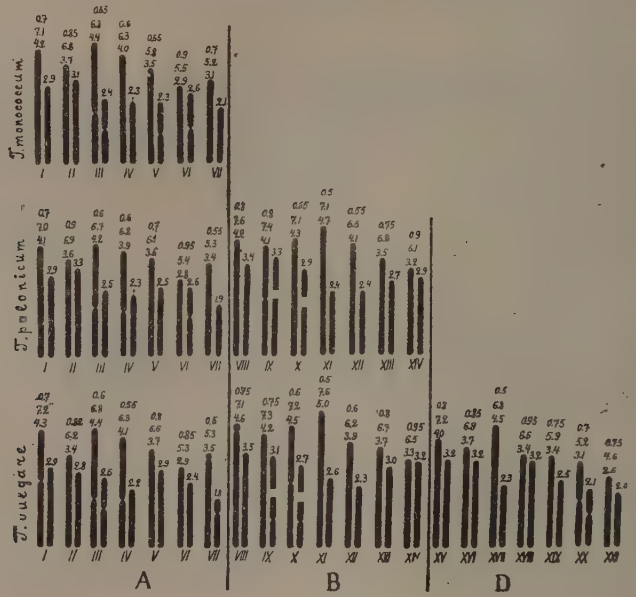

Fig. 2. Quantitative diagrams of the sets of *Tr. monococcum*, *Tr. polonicum* and *Tr. vulgare*. Numerical designation for each set: Roman numerals—chromosome types; Arabian numerals: upper row—ratio of arms; middle row—total chromosome length; lower row—length of the greater arm; farther below—length of the smaller arm. *A*, *B*, *D*—the three genomes. Magnification 2500.

differentiation unfortunately is not suited to full extent for establishing homology of the chromosomes, especially when they are «extracted» from different plates; one and the same type of chromosomes may here be erroneously taken for two, or some of the non-differentiated and, moreover, similar types may be omitted. Just in this way and, moreover, without any measurements Kagawa has established «chromosome types» in different wheats (7). In spite of the fact that this writer has demonstrated the recurrence of these «types» in a number of species, his evidence appears to be doubtful; the doubt is strengthened by the fact that his data are far from being in accord with those of ours. The only correct method which was applied by us is the analysis of all the chromosomes from a single plate.

In connexion with instability of the majority of secondary differentiations of the chromosomes they could be only partly used for establishing «types» (III, IV, VI, IX, X); the whole of the comparative analysis was basically founded on the relative dimensions of the chromosomes and of their arms.

As may be seen from Fig. 2, it was possible to find in *Tr. vulgare* 14 chromosomes which are very close to the 14 chromosomes of *Tr. polonicum*, i. e. which constitute its genomes *A* and *B*. The remaining seven will thus be the genome *D*. Two smallest chromosomes of *Tr. vulgare* belong here.

The comparison of the above-mentioned 14 chromosomes of *Tr. polonicum* with *Tr. monococcum* allows isolation of the most similar types and establishing (with a certain degree of probability) the genome *A* common to all the wheat species. However, there is less certainty here owing to a lower degree of «conjugational» compatibility between the chromosomes of einkorn species and those of the hard wheat as well as to the possibility of structural differences even among morphologically very similar chromosomes. Most difficult is the decision with regard to the chromosomes with appendices: whether both of them belong to the same genome *B*, as such chromosomes appear to be lacking in the einkorn group, or one of them belongs to the genome *A*, the other to the genome *B*, the appendix having «not yet evolved» in seven-chromosome wheats*. In the latter case one of the chromosomes with appendix of *Tr. polonicum* and *Tr. vulgare* (*X*) should exchange places with the chromosome I belonging to *A* genome and similar to it in all the remaining respects. In connexion with the data communicated above the question arises on the degree of «compatibility» of the chromosomes of the very genomes *A* and *B*; it is suggested by chromosome conjugation in hybrids ([10]) especially in connexion with autosyndesis in *Tr. vulgare* ([11], [12]). Comparison in this respect of the genomes *A* and *B* (when the two just mentioned possible cases are considered) gives three similar pairs (I—X, III—XII, V—XIII) which is in exact agreement with the data on chromosome conjugation in the hybrid $A \times AB$ ([10]); the remaining 4 chromosomes are strongly different. There is no compatibility between the genomes *A* and *B*, on the one hand, and the genome *D*, on the other. Two pairs are strongly different in either case, and one of the pairs of the genome *D*, which represent the smallest chromosome of the set of the soft wheat (XXI—4.6 μ), has no analogue in any of the existing genomes. The above data represent a more detailed verification of Kagawa's conclusions ([7]) on the morphological difference of the genomes of wheat. It should be remarked, however, that the basic data of quantitative nature which were referred to by him could not be supported by us; the length ratio of the largest and smallest chromosomes (selected by him approximately) which should be strongly different in *Tr. polonicum* (100 : 53) and *monococcum* (100 : 68) appeared to be very near to each other in our studies (100 : 71 and 100 : 73, respectively).

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* It should be noted in this connexion that among very many plates lacking analogous chromosomes with appendices in one single case they were found in *Tr. aegilopoides* (Fig. 1, *D*, *E*).

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GENETICS

REDUCTION DIVISION IN THE 16-CHROMOSOME RYE

By A. I. FETISSOV

(Communicated by N. I. Vavilov, Member of the Academy, 26. VII. 1939)

Aside from the ordinary 14-chromosome rye there notably occur individuals with 16 chromosomes possessing two additional chromosomes. These often remain at meiosis univalent, lag on the equator, sometimes split and are distributed between the daughter cells in different ways (1). Our study on this race has revealed, however, much more varied and stronger deviations of the reduction division which were far beyond the limits of the behaviour of the «extra-chromosomes». At diakinesis, along with regular formation of eight bivalents cases were described (1,2) when the «accessory» chromosomes proved to be separated. However, aside from this it occurs, although considerably less often, that a greater number of chromosomes fail to conjugate. Thus, only half of the chromosomes represented in Fig. 1 are united into bivalents, the remaining 8 chromosomes being univalent. In Fig. 2 we can see only two bivalents, the remaining 12 chromosomes being univalent, whereas in Fig. 3 there is a complete absence of chromosome conjugation.

Along with phenomena of failure of conjugation, fragmentation of the chromosomes is also rather common in the 16-chromosome rye; it is also observed at diakinesis. In Fig. 3 we see 6 bivalents, one of which has a clearly shortened component, 4 univalents and a fragment. In Fig. 4 there are 3 free fragments (I, II, III) aside from 8 bivalents.

In accord with the phenomena found at diakinesis, at metaphases, too, cases of asyndesis and fragmentation were observed. Not only «accessory» chromosomes, but others as well can be present in univalent state. Fig. 5 shows 6 bivalents, 4 univalent chromosomes and a fragment; in Fig. 6 are shown 5 bivalents, 6 split univalent chromosomes and 2 fragments. All the 16 univalents are represented in Fig. 7 and their 32 halves at anaphase—in Fig. 8.

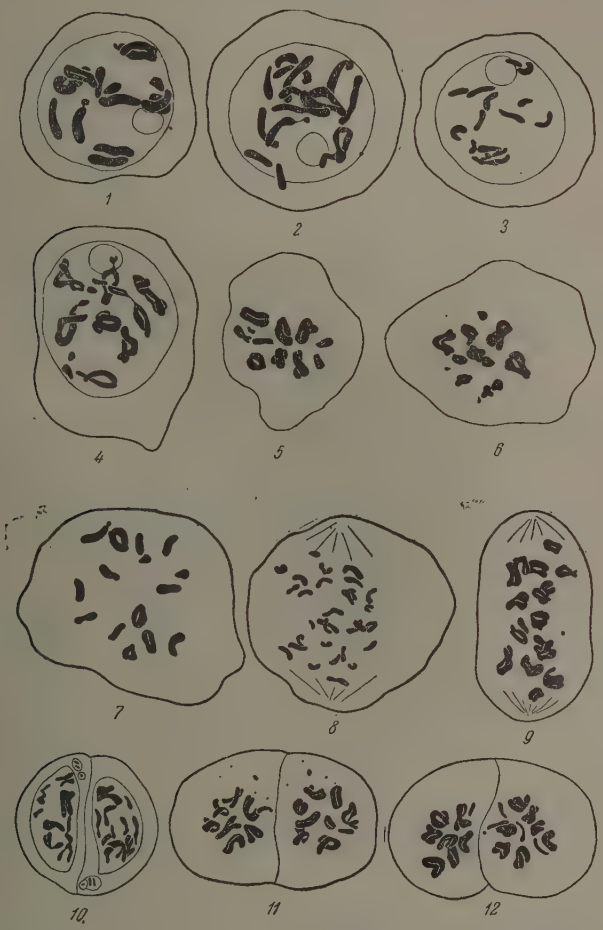
At anaphases of heterotypic division, aside from the wholly normal disjunction of the chromosomes and their distribution between poles, numerous cases of both «lagging» and «advancing» of the chromosomes are observed, including disorderly separation of all the chromosomes (Fig. 9). Some examples of the behaviour and further fate of the fragments are shown in Fig. 10, where the fragments were normally distributed at the anaphase of the homeotypic division, and at formation of the dyad nuclei occurred to be extruded into the plasm beyond the limits of the nucleus in the two sister-cells.

A similar irregular division of the fragments may be seen in Fig. 11, where there are equal numbers (5) of small fragments in each cell of the dyads. In the case in question one of the univalents has split and its two halves were distributed between the sister-cells, whereas the other without yet being split has got into the one of the sister-cells (the right one).

Fig. 12 shows equal numbers (7) of split chromosomes in each sister-cell; aside from this, however, in the one sister-cell there is a large fragment and in the other a small one together with 4 undivided chromosomes; all the four halves of the two split univalents have thus got into a common sister-cell.

At anaphases of homeotypic division, along with the commonest normal disjunction cells are also found, where a certain proportion of chromosomes lag on the equator during distribution.

In the majority of cases the tetrad formation has a normal character, although tetrad cells are rather common which contain various inclusions in a form of isolated fragments or individual chromosomes.



On the basis of the above-described aspects of the reduction division which demonstrate occurrence of fragmentation and failure of pairing of a varying number of chromosomes, one should expect in the progeny of the 16-chromosome rye production of plants not only possessing other chromosome numbers ([3],[4]) but, possibly, modified chromosome morphology, too.

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CYTOGENETICS

CHROMOSOME ALTERATIONS AS A FACTOR OF DIVERGENCE OF FORMS. I. NEW EXPERIMENTALLY PRODUCED STRAINS OF *C. TECTORUM* WHICH ARE PHYSIOLOGICALLY ISOLATED FROM THE ORIGINAL FORMS OWING TO RECIPROCAL TRANSLOCATION

By HELEN GERASSIMOVA

(Communicated by N. I. Vavilov, Member of the Academy, 1. VIII. 1939)

As demonstrated by Darwin, formation of species rests on divergence of once closely related forms. It is quite natural therefore, that lack of experimental evidence in this particular field was especially evaluated by anti-Darwinists. In particular, they often argued somewhat as follows: «if intraspecific races really were incipient species, when and how do they cease to mix with one another to become distinct as real species? As long as no one has experimentally created a new form fertile inter se but forming sterile hybrids with individuals of the species to which it originally belonged, Darwin's conclusion remains unwarranted». One has to admit that lack of such evidence is a great gap in the chain of our arguments; in fact, there is hardly any need to argue at present that factors preventing intermingling of forms play an outstanding rôle among others which take part in causing divergence.

From literary data as well as from our own studies we arrived long ago at a conclusion that structural chromosome changes (in the first place exchange between non-homologous chromosomes) are of outstanding importance as they cause sterility of hybrids between forms differing in the structure of their chromosomes.

During a number of years we were conducting experiments, the aim of which was producing a new form differing in each its chromosome from the one which served as material for its creation; the difference should have been of the rank existing between species of *Crepis*. As a material was selected the annual composite *Crepis tectorum* L. which possesses only 4 pairs of very distinct chromosomes. The problem consisted in producing interchange (reciprocal translocation) between chromosomes of different pairs, and besides, in such a manner as to get wholly fertile and constant forms. The work required 5 years for its completion and, as may be seen from the following, has led to the result aimed; at the present time two chromosomal forms are already made that are fertile inter se but produce markedly sterile hybrids when crossed to their progenitor, the normal *C. tectorum*. They differ in their chromosomes from ordinary *C. tectorum* more than do many natural species. The new forms received the names *Crepis nova* I and *Crepis nova* II.

Here is a brief account of the history of their production. A distinct and wholly self fertile strain of *Crepis tectorum* was selected; it differed from the other known forms of the same species in lacking dark pigment in stigmas and involucral bracts («blond»). Somatic chromosomes of this original strain are represented in Fig. 1, *a*.

In the summer 1934 pollen collected from this strain was treated with X-rays and applied to stigmas of emasculated florets. All the plants thus produced were studied cytologically in 1935 and among translocants obtained a suitable translocation between the *A*- and *D*-chromosomes was picked out. It was, naturally, in heterozygous state (Fig. 1, *d*) and only in 1936 could it be transferred into homozygous state (Fig. 1, *e*) by means of selection among the progeny produced by self-pollination of the heterozygote. It required again extensive cytological analysis.

The translocation between the other two chromosomes, *B* and *C*, was received from N. K. Shkvarnikov; it was in homozygous state from the beginning as it was picked up in other studies among progenies of the material X-rayed in 1931 by M. Navashin. Somatic chromosomes of the heterozygote are represented in Fig. 1, *b*, those of the homozygote—in Fig. 1, *c*.

It should be noted here that plants which possessed structurally modified chromosomes (both in homozygous and in heterozygous state) did not differ perceptibly from the normal plants of *C. tectorum*; nor did they differ from one another. The only exception to this was fertility; while the homozygous forms, both when self or cross-pollinated, proved to be normally fertile, heterozygotes (in full accord with our original expectation) exhibited a nearly twice reduced fertility.

In 1937 the two homozygous translocant forms were crossed with each other and hybrids were raised in the same season. The chromosome sets of these hybrids contained not a single pair of identical chromosomes (Fig. 1, *f*) as they owed their origin to gametes which differed in each chromosome. They again differed in no way from the normal plants except for fertility, this time it was only 36% (the normal control plants showed 89% fertility); when self-pollinated they produced 31% of good seeds (against 80% in the control).

Seeds obtained from self-pollination of these plants gave in 1938 the F_2 consisting of various forms, as should have been anticipated on the basis of the law of segregation and the conditions of chromosomal balance (Fig. 1, *g—o*). These forms were as follows: 1) normal plants (Fig. 1, *g*); 2) those heterozygous for one of the two pairs of translocated chromosomes, *BC* (Fig. 1, *h*) or *AD* (Fig. 1, *i*) and those heterozygous for the two pairs at the same time (Fig. 1, *l*): 3) forms homozygous for the one (Fig. 1, *j*) or for the other (Fig. 1, *k*) of these chromosome pairs. All the forms enumerated above merely repeated those which were obtained earlier and served as a material for the production of the parental form heterozygous for all the four chromosome pairs. The following forms are new combinations: 4) segregating form homozygous for the one pair of the translocated chromosomes and heterozygous for the other (Fig. 1, *m* and *n*) and, lastly, 5) the constant form homozygous for all the four translocated chromosome pairs (Fig. 1, *o*, and Fig. 2). This was the first of the new experimentally produced chromosomal forms—*Crepis nova* I.

In an analogous way was obtained in the spring 1939 the second form, *Crepis nova* II. It differed from *C. nova* I in its chromosomes, although translocation was effected here between the same chromosome pairs *A—D* and *B—C* (Fig. 3). It had an advantage before *C. nova* I, first, in possessing better identifiable V-shaped chromosome pairs (owing to size difference) and, secondly, in the absence of extremely small chromosomes; as will be shown below,

the latter may lead to certain irregularities of meiosis and, consequently, to impairment of fertility.

The two forms were morphologically indistinguishable from the original one and were no less uniform than the latter. They were represented by well

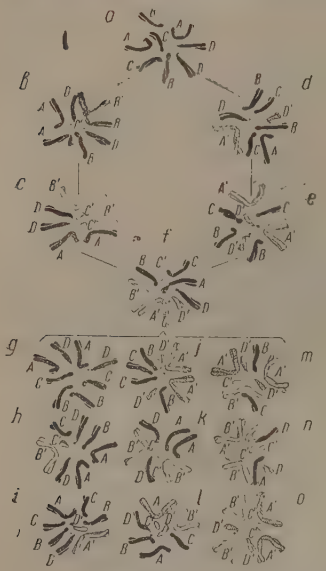

Fig. 1.

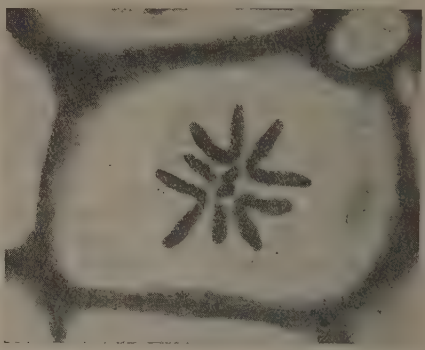

Fig. 2.

Fig. 3.

Fig. 1. Somatic chromosomes of the plants which gave rise to *Crepis nova* I (the history of its production). Normal chromosomes are drawn in solid black. *a*—Original normal plant of *Crepis tectorum* L. (*AABBCCDD*) (the four normal chromosome types are designated here and subsequently with capital letters *A*, *B*, *C* and *D*). *b*—Heterozygous translocant (*AABB′CC′DD*); *B′* and *C′* are the translocated chromosomes. The *B*-chromosome has received from the *C*-chromosome its whole distal limb and acquired therefore large size and V-shaped form (*B′*); the *C*-chromosome received in exchange just a very small portion of the *B*-chromosome and became very small (*C′*). *c*—Same, in homozygous state (*AAB′B′C′C′DD*); obtained through selfing the preceding form. *d*—Heterozygous translocant (*AA′BBCCDD′*); *A′* and *D′* are the translocated chromosomes. *A*-chromosome received from *D* a considerable part of its distal limb and became thus very large and nearly isobrachial (*A′*); the *D*-chromosome received from *A* just a small amount and became small (*D′*). *e*—Same, in homozygous state (*A′A′BBCCD′D′*); obtained through selfing the preceding form. *f*—The F_1 hybrid between the above two homozygous translocants (*AA′BB′CC′DD′*); no paired chromosomes are present. *g*—*o*—Forms actually obtained in the progeny from selfing the preceding form heterozygous for all the 4 chromosome pairs (*AA′BB′CC′DD′*). *g*—Normal plant (*AABBCCDD*). *h*—Translocant heterozygous for the one chromosome pair (*AABB′CC′DD*). *i*—Translocant homozygous for the same chromosomes (*AAB′B′C′C′DD*). *i*—Translocant heterozygous for the other chromosome pair (*AA′BBCCDD′*). *k*—Translocant homozygous for the same chromosome (*A′A′BBCCD′D′*). *l*—Full heterozygote (like F_1) (*AA′BB′CC′DD′*). *m*—Translocant heterozygous for one chromosome pair *B*—*C* and homozygous for another (*A′A′BB′CC′D′D′*). *n* Translocant heterozygous for the chromosome pair *AD* and homozygous for the other pair (*AA′B′B′C′C′DD′*). *o* — Translocant homozygous for the two chromosome pairs (*A′A′B′B′C′C′D′D′*).—*Crepis nova* I.

Fig. 2. Somatic chromosomes of *Crepis nova* I. Photomicrograph.

Fig. 3. *Crepis nova* II, somatic chromosomes. Homozygous translocation between the same chromosomes as in *C. nova* I. The portion received by the *B*-chromosome from the *C*-chromosome is, however, smaller here than in the case of *C. nova* I. Hence greater morphological difference between the two V-shaped chromosomes and larger size of the *C*-chromosomes.

developed abundantly flowering individuals; their fertility did not differ materially from that in the normal strain.

Only *C. nova* I has been subjected to detailed study as it could be raised in a large number of individuals. Its seeds showed very good germination-power (96%); 100% of the seedlings obtained survived. Cytological examina-

Fig. 4. Somatic chromosomes and reduction division in the original normal form of *C. tectorum* (left column), in *C. nova* I (right column) and in their F_1 hybrid heterozygous for all the 4 chromosome pairs (central column). In the original normal *C. tectorum* as well as in *C. nova* I reduction division is entirely normal. In the hybrid between the two, on the contrary, it is abnormal; owing to these abnormalities (see text) strong sterility is produced (in the two upper figures of reduction division the quadrivalents for the sake of clearness are shown on the right-hand side somewhat drawn apart).

tion has shown that all the plants grown of seed obtained from self-pollination of *C. nova* I had identical chromosomal constitution except for occasional trisomic ones (the reason for their occurrence will be explained below). *C. nova* I may be hybridized with the ordinary form of *C. tectorum*; however, the hybrid produced has low fertility (about 30% seed setting when self-pollinated and slightly more when open-pollinated).

Here are thus all grounds to consider *C. nova* I a new distinct form which is to a great extent isolated from the bulk of the species, *C. tectorum*, although not yet differing from it morphologically.

The study of meiosis has shown that *C. nova* I possesses an entirely normal mechanism of reproduction. Beginning by the earliest diakinesis we find here four bivalents which correspond to the 4 pairs of somatic chromosomes of *C. nova* I: two large bivalents (formed of the V-shaped chromosomes *A'*

and B'), one bivalent of medium size (composed of the satellited chromosomes D') which is constantly adjoining the nucleolus, and one of a very small size formed of the two small C-chromosomes (Fig. 4, right column). In the I metaphase we similarly observed four bivalents of corresponding sizes and, finally, an entirely regular disjunction took place at the I anaphase. Homeotypic division was entirely normal.

The only deviation from the normal course of meiosis occurs sometimes with respect to the smallest chromosome pair (C'). Owing to their extremely small size they fail sometimes to «find» each other and, therefore, do not conjugate. The force of their mutual attraction is evidently so small that they have no time to conjugate in case they happen to lie too far from each other at prophase and remain single at the moment of anaphase. Hence certain irregularity of their further behaviour, an irregularity of the sort typical of unpaired meiotic chromosomes in general, viz. lagging, non-disjunction, etc. A certain proportion of trisomic forms in the progeny and slightly reduced fertility are the result.

There are no grounds to expect even as slight an irregularity of behaviour in *Crepis nova* II which has no such a disproportion of chromosome sizes. As a matter of fact the first heads which matured to the moment of closing this manuscript showed excellent fertility.

No irregularities of meiosis were found in the original form of *C. tectorum* (Fig. 4, left column).

The study of meiosis in the hybrids between *C. nova* I and the original line of *C. tectorum* has shown that the above-noted high sterility was a result of great irregularities of meiotic behaviour which could result in nothing but elimination of certain sorts of gametes. It appeared indeed that the chromosomes of the hybrid instead of forming 4 bivalents are assembled in 2 groups, 4 chromosomes in each. Exact study has shown that these quadrivalents were rings made up of 2 translocated and 2 normal chromosomes each; the chromosomes composing them were arranged in the manner which could be expected from the assumption of reciprocal character of translocations. However, it could be very well seen at late diakinesis and at metaphase that instead of rings two open chains were present in each cell. The fact that no closed rings were formed should be evidently explained through very slight attraction between the A and D' and B and C'-chromosomes owing to the extremely small sizes of the portions received by the D' from A and by the C' from B. Direct observation made it possible to establish that the arrangement of the chromosomes in each ring was constant; to the two ends of the biggest translocated V-shaped chromosomes A' and B' were associated the corresponding normal chromosomes (A and D with A', B and C with B') and, finally, the rings are closed up by the smallest chromosomes (C' or D'). As indicated above, the latter are very loosely associated with the A and B-chromosomes, so that there are most often two open chains instead of closed rings. The A—D chain could be easily distinguished from the B—C chain, as the former, first, at the diakinesis always remained closely associated with the nucleolus, secondly, later on could be recognized owing to its somewhat larger size. Finally, the D-chromosome could be always recognized through its characteristic «link», whereas the B' could be distinguished from the C' through its larger size (Fig. 4, middle column).

Relative to each other the two chains were arranged at random, i. e. the central V-shaped chromosomes could be turned toward the one and the same pole or toward the opposite poles.

It is easy to see that owing to these peculiar conditions existing in the hybrid *C. nova* I $\times$ *C. tectorum*, first, chromosome distribution should be to a certain extent predetermined, and, secondly, that certain sorts of spores

formed should be unviable owing to unbalanced condition of the chromosome sets contained in them.

As a matter of fact the viable gametes can result only from alternating distribution of the chromosomes to poles. As the order of the chromosomes composing the chains is constant (see above), viz., *AA'DD'* and *BB'CC'*, only alternating assortment can produce gametes possessing balanced chromosome sets; thus, from the four chromosomes forming each chain two normal ones should go to the one pole and two translocated ones—to the opposite pole, i. e. *AD* and *A'D'* from the one chain and *BC* and *B'C'* from the other. Thus, all the four vaible kinds of gametes are found, viz., *ABCD*, *A'B'C'D'*, *A'BCD'* and *AB'C'D*.

If chromosomes were always assorted in the above manner, we should have always 100% of viable gametes. In reality the fertility of the hybrid is only about 30% (see above). It follows from this that chromosomes are assorted in other ways, too; it is probable that chance assortment takes place so that altogether about 70% unviable gametes are formed. It remains, however, to be seen whether the sterility is purely gametic or other circumstances, too, play a part here.

In case of random distribution of chromosomes the following additional 12 kinds of gametes should be formed: *A'BCD*, *AB'CD*, *ABC'D*, *ABCD'*, *A'B'CD*, *A'BC'D*, *AB'CD'*, *ABC'D'*, *A'B'C'D*, *A'B'CD'*, *A'BC'D'* and *AB'C'D'*; all of them should be supposed to be unviable owing either to excess or to deficiency of chromosome material. Out of the 16 possible kinds there survive only 4, so that 75% cannot take part in formation of zygotes; cytological analysis of the progeny has fully corroborated this assumption. As pointed out above, the progeny consisted, in full accord with expectation, of the following 9 kinds of individuals (Fig. 1, *g—e*); (1) *AABBCCDD*, (2) *AA'BBCCDD'*, (3) *AABB'CC'DD*, (4) *A'A'BBCCD'D'*, (5) *AAB'B'C'C'DD* (6) *AA'BB'CC'DD'*, (7) *A'A'BB'CC'D'D'*, (8) *AA'B'B'C'C'DD'* and (9) *A'A'B'B'C'C'D'D'*.

The fertility, it is true, somewhat exceeded 25% (31—35%) which showed that viable gametes were somewhat more abundant as compared to expectation; probably, configuration of the chains and their position with regard to the spindle favoured alternating disjunction of the chromosomes which actually took here place somewhat more often than any other.

We have seen thus that the disturbance of the reduction division found in our hybrid constitutes a real barrier between the two constant forms, the original *C. tectorum* and the newly created *C. nova*.

The efficiency of this barrier becomes quite clear to us when we take into account that isolation is not limited here to a mere reduction in fertility of the hybrid, but involves another factor, viz., recombination of parental characters. As a matter of fact, the absence of the majority of the kinds of gametes with recombined parental chromosomes nearly precludes the chromosome recombinations in the progeny; besides, the anomalous conjugation and structural incompatibility of the conjugating chromosomes strongly control crossing-over which produces, in case it occurs at all, new structural reorganizations, in their turn causing additional sterility. The latter circumstance became obvious after an analysis of 1052 individuals representing the progeny of another more complex hybrid where 6 chromosomes formed a chain and only two of them showed regular conjugation; as a result up to 20% of entirely new chromosomes were discovered in the progeny. Composite translocation thus results in an increase in sterile forms. It becomes inevitable, therefore, that the progeny of the hybrids in question contains a very limited proportion of individuals with intermediate characters, but consists to a large extent of the two parental types and of individuals which repeat the original hybrid.

In other words, there exists a situation characteristic of a hybrid between two genuine species.

We are thus justified in concluding that chromosomal forms of the kind described in this paper possess already the most important property of «incipient species». The attack at the experimental Darwinism referred to at the introduction to this paper becomes entirely devoid of any ground as our knowledge on the nature of variation increases.

Although our new forms *C. nova* I and *C. nova* II still are morphologically indistinguishable from the initial form of *C. tectorum*, accumulation of mutational changes should undoubtedly lead in future to such distinction.

At the present we are carrying out work on further isolation of these forms from the original one by producing secondary translocations which should recombine chromosomal material in a still more complex and profound manner. This should beyond doubt result in a still greater isolation of forms which originally constituted a common population.

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CYTOGENETICS

EXPERIMENTAL ANALYSIS OF THE NON-RANDOM DISJUNCTION OF NON-HOMOLOGOUS CHROMOSOMES

By B. F. KOZHEVNIKOV

(Communicated by N. I. Vavilov, Member of the Academy. 10. VII. 1939)

The writer makes an attempt to investigate in the present work the phenomenon of non-random disjunction of non-homologous chromosomes which was predicted on the basis of writer's hypotheses and later verified experimentally. It is the most wide spread opinion among geneticists that movement of the chromosomes toward opposite poles as well as their conjugation are the results of activities of the forces of homological affinity. The very existence of these forces and their decisive rôle in conjugation of homologues are supported by fully convincing evidence. The conviction that the same forces cause disjunction of the chromosomes is based on the fact that chromosomes which have conjugated with each other later go to opposite poles, especially in case there was crossing-over. However, there are cases when conjugation and even crossing-over do not result in subsequent wandering of the chromosomes to the opposite poles. This is found in gonia as well as in the soma, where conjugation and even crossing-over are observed, but there occurs no assortment of the conjugated chromosomes to the opposite poles. This suggests the idea that the cause of disjunction may be of another nature. Besides, cases are known when fragments of a chromosome disjoin which are deprived of spindle fibers; this obviously shows that the rôle played by the spindle fibers is not a decisive one.

Upon consideration of the data by Bridges on the progeny of triploid females, the writer has advanced a hypothesis which accounts for chromosome disjunction on a different basis than does the modern genetics. Bridges' data demonstrate that the single *X*-chromosome goes much oftener together with a diploid set of autosomes, whereas the two *X*-chromosomes more often wander with the haploid one. It was attempted to explain this by an inherent tendency of the ovocyte to divide automatically the whole mass of the chromatin into equal halves. However, in those cases when two of the three *X*-chromosomes of the triploid female are attached to each other, this peculiarity of chromosome disjunction nearly disappears, although the chromatin mass remains unchanged. Probably, an interaction between the non-homologous chromosomes takes place here and it is the cause of the regularity observed. Taking into account the data by Beadle ([1]) on disturbance in crossing-over in translocation when the recipient is present in haploid condition, as well as the considerations and facts contained in the work by Dubinin, Sokolov, Tiniakov and Sakharov ([2]), in which a conclusion is reached that disturbance in crossing-over observed in translocations is caused by the attraction of the chromosomes to the center, we should conclude that it is the bouquet-stage of meiosis when is determined the wandering of any given chromosome to the one or the other of the poles. Let us imagine now that at the

bouquet-stage in the ovocyte of the triploid female the chromosomes are arranged about in the same manner as often seen on slides made of salivary material, i. e. that their proximal portions are nearer to the center whereas the distal ones are directed away from the center, thus forming a ring or a chain arranged in one level (Fig. 1). Suppose now that the disjunction of the

Fig. 1. Representing an ovocyte of the female 3 N at the bouquet-stage. The middle X-chromosome and 2 sets of autosomes possess identical charges and go to the same pole.

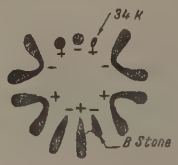

Fig. 2. Representing an ovocyte of an experimental female, duplication *B, Stone* and duplication 34 K; possess opposite charges and move to opposite poles.

chromosomes is caused not by the forces of homological affinity, but by forces resembling the electrical forces in their action (perhaps even by the electrical forces themselves), and the result will be as follows. If the middle X-chromosome will possess a +charge, the other two located right and left from it should have —charge as a result of induction. Autosomes adjoining the outer X-chromosomes will possess a +charge, etc. In case chromosomes possessing charges of equal sizes will go to the same pole, one can easily see that two sets of autosomes should go together with the single X-chromosome, whereas a single set of autosomes should accompany the two X-chromosomes. In the same way one can account for the inheritance of duplications possessing independent spindle fiber. The conjugating chromosomes are arranged in a level, normal chromosomes lie side by side and the duplication is located to the one side owing to a greater homological affinity of the normal chromosomes. In this connexion the data by Sturtevant on the preponderant disjunction of a duplication of the IV chromosome are of interest. These data may be probably interpreted only when our ideas are applied. The hypotheses advanced above allowed the writer to arrange an experiment for its verification. The writer has produced a *Dr. melanogaster* line which contained, aside from a normal set of chromosomes, one duplication in the X-chromosome and one in the IV. The two duplications possessed independent spindle fibers. The writer was led by the following considerations. If the chromosomes form a ring or chain at the bouquet-stage (as described above), their arrangement in the structure in question containing a duplication in the X-chromosome and in the IV chromosome should be of such a sort, that non-homologous duplications should receive opposite charges and go to opposite poles, in case the hypothesis is correct; on the other hand, if the hypothesis is incorrect, they should be assorted at random. As normal chromosomes attract each other stronger than duplications do, they should lie side by side whereas the duplication should be located laterally. When chromosomes receive a charge, a phenomenon is observed which is similar to that described in triploid females. If the central X-chromosome receives a +charge, the outer X-chromosome and the duplication will receive a —charge due to induction. The IV chromosomes, no matter whether or not they happen to lie side by side with the X-chromosomes, anyhow will receive a definite charge transmitted along chromosome chain. In case of the outermost IV chromosomes these charges should be here of positive sign. As the duplication of the IV chromosome will lie at the one side, it should receive a +charge. Consequently,

the duplications should go to opposite poles as they are differently charged in spite of their being homologous.

Let us describe in detail the way in which the experiment was arranged. The females applied for the crosses had two normal *X*-chromosomes containing the genes *y w* in each and a duplication in the right portion of the *X*-chromosomes which was obtained from the line containing the translocation *Bar Stone*. This duplication was an *X*-chromosome truncated at the *Bar* locus; besides, the gene *Bar* was preserved in the translocation and this was very important as this gene played the rôle of indicator of the duplication. The two IV chromosomes contained in the experimental females were normal. The duplication in the IV chromosome possessed by them (34 K) consisted of the whole inert portion of the IV chromosome (the active one was absent) and of a few disks of the left end of the *X*-chromosome (one of them bore the normal allelomorph of the gene *y* which was used as the indicator of the duplication). This duplication (34 K) strikingly resembled that which served Sturtevant to investigate the preponderant disjunction of the IV chromosomes ([1]): it showed the same peculiarities of disjunction. Females *yw/yw B. Stone* 34 K were crossed with males *y*. Only females were registered, as in males bearing duplication vitality was too much reduced. The following 4 basic classes of females were expected: yellow *Bar*, yellow, grey *Bar*, grey and two classes of non-disjunction females, yellow white-eyed and grey white-eyed. According to our hypothesis, the first and the fourth classes should occur in excess as compared to the second and third ones. In case there occurred absolute preference, the second and third classes should be absent. Presence of the duplication for the *X*-chromosome was recognized by the gene *Bar*, duplication for the IV chromosome—by the grey colour. As different vitality of flies of different genotypes could influence numerical relation of classes, a control experiment was arranged for the sake of comparison. In the control experiment the females had only one single duplication of the *X*-chromosome; they were crossed with males bearing the duplication 34 K.

In case our hypothesis is incorrect, the results in the experiments and in the control should have been the same, as they would depend on random of chromosome assortment in both cases. If the hypothesis were correct, the first and the fourth classes of the experiment should have been present in excess, whereas in the control all the classes should have been represented by equal numbers of flies. Making comparison between the class ratios in experiment and in control, we may easily introduce a correction for vitality. The results are represented in the table.

Experiment ♀♀ *yw/yw B. Stone* 34 K × ♂♂ *y*

Phenotype of the female	Yellow *Bar*	Yellow	Grey *Bar*	Grey	Yellow *w*	Grey *w*
	4015	3777	2343	4106	193	136

Control ♀♀ *yw/yw B. Stone* 34 K × ♂♂ *y*

Phenotype of the female	Yellow *Bar*	Yellow	Grey *Bar*	Grey	Yellow *w*	Grey *w*
	4410	4660	3408	3784	186	107

	Number of females of the 1 and 4 classes	Number of females of the 2 and 3 classes	
Experiment	8121 57.03%	6120 42.97%	$n = 14\,241$ $m = \pm 0.41\%$
Control	8194 50.39%	8068 49.61%	$n = 16\,262$ $m = \pm 0.39\%$
Difference between experiment and control		6.64%	$m_{diff} = \pm 0.57\%$

As may be seen from the data contained in the table, the assortment of the chromosome is not a random one. The duplication of the *X*-chromosome and the duplication of the IV chromosome, in spite of the fact that they are not homologous, more often get to opposite poles. One may object to this by assuming that the inert regions of the sex and IV chromosomes are partly homologous which causes their conjugation and their wandering to the opposite poles. We shall present here only the following argument. Sturtevant has shown that all the three chromosomes (two IV and one duplication II) conjugate together and that duplication of the *X*-chromosome does not show any preponderant disjunction with the IV chromosomes. The data on the secondary non-disjunction in our experiment do not agree with the idea of the homology of the inert regions of the IV and *X*-chromosomes either.

If one follows Bridges in interpretation of the mechanism of the secondary non-disjunction, one should expect the *B. Stone* duplication conjugate with the *X*-chromosome, whereas the other *X*-chromosome should obviously conjugate in our experiment with the duplication 34 K. In this case the gametes which have received two *X*-chromosomes should contain no duplications, whereas our data have demonstrated that in the non-disjunction gametes the duplication 34 K was probably assorted at random.

From our viewpoint secondary non-disjunction occurs when the duplication happens to be the central chromosome out of the three conjugating ones; however, this takes places only in such cases when the forces of attraction are weak and the difference between the attraction forces of the *X*-chromosome and of the duplication is levelled; however, as forces of attraction are weak, expression of the interaction with non-homologous chromosomes is almost nil.

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PLANT PHYSIOLOGY

ORIGIN AND FUNCTIONS OF NODULES ON THE ROOTS OF THE MEADOW FOXTAIL (*ALOPECURUS PRATENSIS* L.)

By V. P. NOGTEV

(Communicated by B. A. Keller, Member of the Academy, 5. VIII. 1939)

It is found by me that the roots of the meadow foxtail *Alopecurus pratensis* L. are supplied with many fine elongated nodules. These nodules are formed in the absorbing zone of the root, on the fine side-branches of the root system near their tips. The nodules attain 6 mm in length, their diameter being of 1 mm or a little more. In the early period of their growth they are semi-transparent, but later on they become brownish-black, nearly quite black, owing to the dying off and peeling of the nodule epidermis supplied with root-hairs, as well as to its replacement by the suberized exoderm.

So far as my investigations have shown, the root nodules of *Alopecurus pratensis* are characteristic of any plant of this species wherever it may grow. These nodules are discovered by me even in a herbarium specimen of the meadow foxtail collected by Ledebur in the Altai near Ridersk in 1826 (the herbarium of the Academy of Sciences of the USSR). I was, however, the first to take notice of such typical morphological characteristic, specific for *Alopecurus pratensis*, which shows that the root system of grass plants is not studied enough as yet.

The investigation of the anatomic structure of *Alopecurus pratensis* root nodules showed that morphogenesis of nodules is due to the local profuse growth of cortical parenchyma in the zone of root hairs. In all cases small bacteria having the shape of short rods with rounded tips were found in the cells of the cortical parenchyma. Bacteria were isolated in a pure culture and proved to be spore-forming. Their development was traced on meat-pepton and leguminous agar, Ashby nitrogen-free medium and in Beyerink and Vinogradsky liquid nitrogen-free media. In all these media the bacteria were thriving, their cells varying in size. This size is maximum in the case of meat-pepton agar and minimum in that of Beyerink and Vinogradsky liquid nitrogen-free media. The fact that bacteria thrive even in Beyerink and Vinogradsky nitrogen-free water media indicates the ability of the bacteria to fix molecular nitrogen of the atmosphere. I believe that *Alopecurus pratensis* bacteria inhibiting the root nodules of this grass plant represent a new species of bacteria (species nova). As this bacterium differs from nodule bacteria of leguminous plants in forming spores, it is reckoned by me among bacilla and I name it *Bacillus Alopecuri* Nogt., that is «foxtail» bacterium (the Russian and Latin diagnoses of the foxtail bacterium are given by me in the Botanical Journal of the USSR, № 2, vol. 23, 1938).

I believe the foxtail bacterium to play an essential rôle in the balance of nitrogenous nutrition of *Alopecurus pratensis*, making the atmospheric molecular nitrogen available for this plant nutrition. The most probable origin of *Bacillus Alopecuri* Nogt. is from some rhizospheric bacterium which had penetrated through the root-hair into the foxtail roots and adapted itself to the symbiosis with this grass plant.

In summer the cortical parenchyma of the foxtail nodules is filled with starch grains besides bacteria. Part of the carbohydrates reaching the nodules is sure to be used by the foxtail nodule bacteria for their nutrition, but most of the starch grains filling the nodules are laid in store, to permit the meadow foxtail to start growth in meadows immediately after the spring water recedes. In fact the meadow foxtail is known to develop its stems to blossom and to bear earlier than do all other grasses, after the retreat of the spring flood. Hence the root nodules of *Alopecurus pratensis*, besides the nitrogen-fixing function we admitted, serve to store starch. Though the grains of starch in store are found in endoderm outside the root nodules, yet taking into consideration a great number of nodules scattered all over the foxtail root system, we have no doubt about the importance of these nodules as starch-storing organs.

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PLANT PHYSIOLOGY

TO THE METHODICS OF THE ISOLATION OF *BACILLUS ALOPECURI* NOGT.

By A. A. MUDROVA

(Communicated by B. A. Keller, Member of the Academy, 5. VIII. 1939)

Prof. Nogtev discovered nodules on the roots of *Alopecurus pratensis* L. He investigated the structure of these nodules and found that their parenchyma contained bacteria belonging, according to him, to a particular species which he described and named *Bacillus Alopecuri* Nogt.

Though *Bac. Alopecuri* had been isolated in pure culture in the laboratory of Prof. Nogtev, however, certain points concerning the methodics of the isolation of this bacillus in pure culture remained obscure.

On the proposition of Prof. V. P. Nogtev I arranged this methodic study for the elucidation of the questions, arising in connexion with the isolation of *Bac. Alopecuri* in pure culture.

At the very beginning of the work employing the methods, used for the isolation of bacteria from the nodules of legumina, it had to be stated that these methods are unsuitable for the isolation of *Bac. Alopecuri*: washing of the nodules of *Alopecurus* in 0.1% sublimate solution for 5 min. not only sterilizes them on the surface, but kills the bacteria within the nodules. To solve this problem, i. e. to establish how to isolate a pure culture of bacteria from the nodules of *Alopecurus*, the following experiments were arranged.

Nodules from one rootlet of an *Alopecurus* plant were washed in sublimate solution for one, two, three, four, five or six minutes; one part of the nodules was left untreated. The untreated nodules and the nodules treated with sublimate and washed in pure sterilized water, were placed on bean-agar in Petri dishes. Colonies appeared around the unsterilized nodules already on the next day. No growth whatever appeared around the sterilized nodules. These nodules were taken off the agar with sterile forceps, crushed in a drop of sterile water each in a separate Petri dish and covered with bean-agar. No colonies appeared, while similar inoculation of bean-agar with crushed unsterile nodules resulted in profuse growth. The colonies were numerous but not uniform.

After this we arranged a second experiment. The time of treatment of the nodules with 0.1% sublimate solution was shortened. Nodules from the same rootlet were exposed to its action for 1—2, 10 per 30 sec. The experiment was repeated five times. The following results were obtained. Nodules sterilized in 0.1% sublimate solution for 1—2 sec. and inoculated into bean-agar Petri dishes gave rise to growth on two occasions, i. e. colonies arose around the nodules. There was no growth around the nodules which had been exposed to the action of 0.1% sublimate solution for 10 or 30 sec.

It was clear that a sure sterilization was achieved by sublimate treatment for at least 10 sec. The respective nodules, after their sterility had been thus tested, were placed into a drop of sterile water in a separate Petri dish each, crushed with the help of a sterile glass rod and covered with sterile bean-agar. Numerous uniform colonies appeared on the agar on the next day. The following interesting phenomenon was observed simultaneously with the inoculation of bean-agar with whole nodules for testing their sterility; nodules of the same term of exposition to sublimate were crushed in sterile water and covered with bean-agar in Petri dishes with the intention to see, how this exposition affects the number of bacteria, contained in the nodules.

It was found that the longer was this exposition, the less bacteria remained in the nodules.

The figures supplied below show that already a 10-sec. exposition decreased considerably the number of bacteria in the nodule. The following colony counts were obtained on Petri dishes inoculated with bacteria squeezed out of nodules, exposed to the action of 0.1% sublimate solution for varying time intervals:

Test 1	Test 2
1—2 sec. — countless colonies	1—2 sec. — countless colonies
10 » — 138 »	10 » — 510 »
30 » — 28 »	30 » — 25 »

It is, of course, possible that the nodules taken for the tests were of varying size; yet such an abrupt decrease of the number of bacteria in a nodule, as was observed after longer exposition to sublimate, induced one to think that sublimate diffused through the thin envelope of the nodule with great speed and killed off the bacteria within it.

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ZOOLOGY

RELATIONSHIPS OF THE GENUS *OSIRIS* F. SMITH AND ITS POSITION IN THE SYSTEM OF BEES (*HYMENOPTERA, APOIDEA*)

By V. V. POPOV

(Communicated by S. A. Zernov, Member of the Academy, 10. VIII. 1939)

Original and independent arising of parasitic genera (and species) in various families and groups of bees has led to notable development in the former of parallel and convergent characters. Morphological adaptations to the parasitic mode of life involve many characters of an insect. The close phylogenetic relation between parasite and host just when the parasitizing of the bee is ensuing, and the divergence and parallel development of the two following thereupon, as well as this parasite's eventual setting to parasitizing in nests of unrelated species of bees, offer a reasonable explanation as to how such parallelisms and divergences arise.

Those who simply suggest phylogenetic kinship for nearly every modern pair of genera «parasite—host» (the so-called German Muller law) and ignore the possibly complex nature of the evolution following immediately upon the beginning of parasitism, are apt to be misled by erroneous phylogenetic approximation. The simplified concept of the immutability of the historically persistent parallel and interrelated divergence of parasite and host, i. e. the strict application of the so-called Furman law to the bees, likewise leads to erroneous conclusions. In doing so one overlooks ecological factors, for instance, that a parasite might pass from one polytropic host to another under conditions of communal or joint nesting which is rather common among bees.

The above observations do not imply a refutation of the laws of Muller and Furman, nor do they undermine the value of the latter toward understanding the evolution of bees, they are merely warning against the simplified application of those laws.

There are not many instances known among bees when direct and close phylogenetic affinity between parasite and host has been actually proved. The group of the species *Nesoprosopis inquilina* among *Nesoprosopis*, the subgenus *Ctenoplectrina* among *Ctenoplectra* and *Lestrimelitta* among *Melipona* appear to fill up the list of recorded occurrence of parasitic species among non-parasitic genera. The examples of direct phylogenetic affinity between two genera—parasite and host—are by far more numerous, however, most of them are likewise imperfectly known, and a number of corresponding pairs in Wheeler's table ([1]), even among those marked as most reliable, need verification.

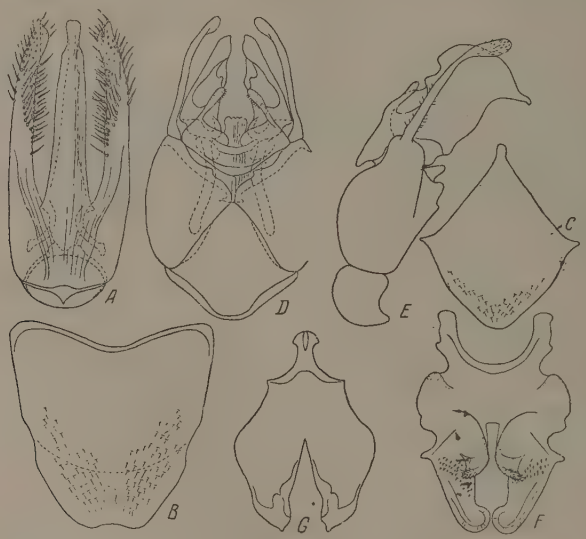
Particular interest deserve cases where various groups of parasitic species are believed to be arising directly from respective groups of hosts. As a clas-

sical example of such a case among our fauna may serve the pair *Psithyrus*—*Bombus* (s. l.). The question as to the mono- or polyphyletic origin of *Psithyrus* has been much discussed and is still debatable.

The present paper deals with the question of relationships between the Central and South American genus *Osiris* whose various groups of species are regarded as derivatives of the endemic Central and South American genus *Tetrapedia* (2).

The author is indebted to Prof. H. Friese for the privilege of studying his material on the genus *Osiris*.

It was Ducke (3) who already pointed out the close relation between *Osiris* and *Tetrapedia*, the former being parasitic on the latter. Wheeler (1) has shared this view. Grutte(2) from a thorough analysis based mainly on «neutral» characters concluded that the subgenus *Osiris* stands near to light-coloured forms of the type *Tetrapedia testacea* and that the subgenus *Coelioxoides* is closely related to dark-coloured forms of the type *T. diversipes*. Having used various systems of characters, Grutte has on theoretical grounds eliminated but one—the system of genitalia characters, whereas even a cursory examination of the characters of genitalia and adjoining sternites in both genera makes obvious the erroneousness of this attitude of Grutte (figure).



Osiris duckei Friese. *A* — dorsal view of the copulatory apparatus; *B* — sternite VII; *C* — sternite VIII. *Tetrapedia testacea* Sm. *D* and *E* — dorsal and lateral views of the copulatory apparatus; *F*—sternite VII; *G*—sternite VIII.

Tetrapedia, among which both dark and light-coloured species were investigated, are unquestionable representatives of the family (or subfamily) *Euceridae*. The structure of stipites, especially of their rather narrow and long apex, sharply separated from the basal part, the complex and fanciful structure of sagittae, particularly the nature of the dorsal bridge between them, the general character of the structure of sternites VII and VIII, in full agreement with many external structural features offer unfailing proof in support of the above contention.

The subgenus *Osiris* (subgenus *Coelioxoides* is not known to me in nature) is representative of those highly specialized parasitic genera which are

artificially united into the heterogeneous family *Nomadidae*. The circle of hosts of the latter is varied though limited within each genus, and alongside of some morphological features of structure bears evidence of their long evolution as parasites. The so-called Muller law in its simplified interpretation does not hold good in this case.

The extremely characteristic structure of the copulatory apparatus and sternites VII and VIII of the male brings *Osiris* closer to *Pasites* (4), *Morgania* (5), *Schmiedeknechtia* and *Neopasites* (*Holcopasites*) (6), i. e. with representatives of the tribes *Ammobatini* and *Neopasitini* in the modern sense, as I was kindly informed by E. G. Linsley and C. D. Michener (7), whereas by a number of external characters *Osiris* inclines to *Nomada*. Thus, the venation in *O. duckei* agrees in detail with that in large *Nomada* or *Andrena*, and only the sharply expressed character of the jugum distinguished the wing of *Osiris* from that of *Andrena*. Two-teethed mandibulae of *Osiris* make it sharply differ from all the enumerated genera; the small and free labrum, from the large *Pasites*, *Morgania*; the general aspect brings it nearer to *Nomada*; and the degree of development of pleural scrubs approximates them rather to *Pasites* and *Morgania*, and still more to *Schmiedeknechtia* and *Neopasites* than to *Nomada*, which have none of them. The presence or absence of pleural scrubs is considered an important characteristic. Handlirsch (7) has established for *Osiris* the tribe *Osirini* (questioningly), placed it next to *Odyneropsidini* in a linear arrangement of tribes. Should a graphic arrangement of a more natural grouping of tribes be attempted, *Osirini* is to occupy a position according to its similarity to other tribes as well.

The structural peculiarities of the abdominal apex of the female *Osiris*, conditioned by parasitism, like in the case of *Paradioxys*, could not but affect the structure of the copulatory apparatus of the male. As a result the elongation of stipites and the fusion of sagittae with penis proceeds convergently in various groups of parasitic bees. Moreover, Grutte admits that a considerable degree of resemblance in details and in the general plan of structure of sternites VII and VIII in various groups is generally possible. Thus, the suggestion may be ventured that many peculiarities of the structure of the copulatory apparatus in *Osiris* are not to be taken as a proof of its direct affinity with other genera. However, the structure of genitalia of *Paradioxys pannonica* and, particularly, of their sternites VII and VIII has not lost the structural characters of genus *Dioxys*. The structure of the basal lobes of sagittae and cardo in *Pasites* and *Morgania* as well as the structure of sternite VIII testify to appreciable differences from *Osiris*. There is a more complete similarity in structure of the genitalia and adjoining sternites in *Osiris*, *Schmiedeknechtia* and *Neopasites*, however, in this case, too, the differences in the structure of cardo, apices of the stipites and sagittae, likewise, speak against the direct approximation of the two genera; this is confirmed by numerous distinctions. Therefore the suggestion of convergent similarity seems to be quite plausible. Just as the extreme form of the genitalia in *Schmiedeknechtia* and *Neopasites* may be linked through the intermediate stage of structure in *Ammobatoides*, to other tribes of *Nomadidae*, so the genital organs of the *Osiris* type could to a certain degree be assumed to incline to *Nomadini*; however, a number of intermediate links remain uncertain.

At the present time deficient knowledge of the morphology of the majority of South American genera of parasitic bees does not allow of a more exact determination of relationships of *Osiris* which is with good reason isolated into a separate tribe, the latter by combination of characters being sharply demarcated from neighbouring tribes. The condition of restricted parasitizing in nests of various hosts emphasizes morphological isolation and the

impossibility of close affinity between the parasites and their hosts. *Osirini* are parasitic on *Tetrapedia* (*Eucaridae*), *Pasites* and, probably, on *Morgania*, of various *Nomiinae*—*Neopasites* and *Schmiedeknechtia*—*Panurgidae*, and, lastly, on *Nomada*—principally *Andrenidae*.

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ZOOLOGY

SUBGENERIC GROUPINGS OF GENUS *PROSOPIS* F. (*HYMENOPTERA*)

By V. V. POPOV

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While studying the fauna *Prosopidae* of Australia, R. C. L. Perkins (1) observed that the genus *Prosopis* is not homogeneous; he arrived at this conclusion upon investigation of the male genitalia and the adjoining sternites. The genitalic system furnishes in this as well as in other groups of bees the best material to form a concept of the actual position of the genus, of its homogeneity (1,2). Metz(3) investigated the genitalic structure of Nearctic genera; Mehely (4), of Palaearctic ones. The studies of the two authors have fully confirmed Perkins' statement. *Prosopis* has a world wide range of distribution; in 1923 Meado Waldo (5) listed over 550 species under this genus; since then their number has somewhat increased; the structure of the male genitalia has been known but in 150 forms, still this genus is rather heterogeneous.

The works of Mehely and, partly, of Metz contain certain grave errors in the treatment of groups (subgenera), their estimation, diagnosis, and the work of the former, moreover, has some deficiencies in nomenclature. We are not discussing here the theoretical part of Mehely's work. The first group of errors is due to the fact that the variations in the genitalic structure of the genus are studied without reference to such variations among the rest of bees. The present paper contains a description of the system of subgenera and their synonymy.

1. Subg. *Abrupta* Mehely 1935. Clypeus with prominent sides, supraclypeal area with a strong rod. Apical lobes of sternite VII long, massive; accessory lobes well developed. Sternite VIII with long basal lobe and long apical lobe; the latter broadened and depressed, set with hair. Stipites broad and short; their apex strongly blunted with outer angles; the outer angle bears long and sparse hairs, the inner one—short and thick setae. Sagittae—narrow dorso-ventrally, nearly parallel-sided. Type: *P. cornuta* Sm.

2. Subg. *Mehelya* nom. nov. (syn. *Barbata* Mehely 1935 nec G. Humphrey 1797 and W. Swainson 1840). Scent glands on sternite VI lacking. Main apical lobes well developed, hairy; accessory lobes are narrow triangles, with marginal plates. Basal lobe of sternite VIII short and broad, the apical one quite short and narrow, feather-haired along the sides of its distal half. Stipites quite narrow, very long with a seemingly disjunct narrow hairy apex, very narrow dorso-ventrally, faintly curved. Type: *P. friesei* Alfk.

3. Subg. *Koptobaster* Alfk. 1912 (syn. *Pseudobranchiata* Mehely 1935). Head narrow, elongate. Median segment truncate; base of segment I blunted. Scent glands on sternite VI strongly developed. Both pairs of apical lobes of sternite VII large, wing-like bearing neither hairs nor plates. Basal lobe of sternite VIII quite short and broad; apical lobe long and narrow, strongly broadened and depressed at the hairy apex. Stipites broad, slightly narrowed in the middle at the feather-haired apex. Sagittae narrow dorso-ventrally, nearly parallel-sided. Type: *P. bifasciata* Jurine.

4. Subg. *Navicularia* Mehely 1935. Scent glands on sternite VI greatly developed. Apical lobes of sternite VI strongly reduced, short, usually narrow; external parts narrow and long, rounded distally; hairs short and rather thick. Sternite VIII rhomboidal; basal lobe short, apical one—narrow and pointed, usually hairless. Stipites rather narrow and elongate, medially curved with hair clothing over the apical half. Sagittae very broad dorso-ventrally, with narrow and short perpendicular apex. Type: *P. variegata* F.

5. Subg. *Prosopis* (F.) (syn. *Modestus* division Metz 1911; *Auricularia* Mehely 1935 nec H. Blainville 1816; *Cingulata* Mehely 1935; *Fascista* Mehely 1935). Scent glands on sternite VI strongly developed. Apical lobes of sternite VII, like in *Navicularia*, however, more strongly developed, as a rule, long and broad, bearing long, usually feathery hairs. Sternite VIII with short and broad basal lobe; the apical lobe is rather short and usually somewhat broadened; blunted or slightly depressed at the apex, rarely pointed and always destitute of pubescence. Stipites like in *Navicularia*, except for being occasionally more expanded distally. Sagittae, as a rule, somewhat narrower than in *Navicularia* and usually bearing in the middle peculiar ear-like appendages. Type *P. bipunctatus* F.

6. Subg. *Dentigera* Mehely 1935 (syn. *Imperfecta* Mehely 1935 ex parte). Scent glands on sternite VI strongly developed. Apical lobes of sternite VII reduced: from small oval hairless plates to lobes of the type of subg. *Prosopis* with pubescence nearly identical to theirs (*P. pilosa*, *P. fertoni*). Sternite VIII short, with short lobes: the basal lobe broad; the apical lobe triangular and hairless; in exceptional cases the apical lobe is elongated in the shape of a considerable spur after the fashion of the subgenus *Navicularia*. Stipites quite narrow and long, sometimes greatly expanded medially in the apical half. Sagittae more or less appreciably (*P. rubicola*) expanded dorso-ventrally; ventral protuberance sometimes strongly developed. Type: *P. brevicornis* Nyl.

7. Subg. *Nesoprosopis* R. C. L. Perkins (syn. *Imperfecta* Mehely 1935 ex parte). Scent glands on sternite VI well developed (*P. pectoralis*). Apical lobes of sternite VII usually long and massive, destitute of plates and almost always of hairs, curved ventrally. Sternite VIII quite short, with a quite short and narrow apex and very long and narrow apical lobe, sometimes exceeding the length of the sternite of the apical lobe, nearly or perfectly perpendicular to the plane of the sternite; the summit of the apical lobe is sometimes bifurcated, flattened and always covered with hairs which are feathery for the greatest part; base of the lobe always keeled. Stipites quite narrow and elongate, sometimes broadening at the base; their apical half beset with feathery hairs. Sagittae feebly expanded dorso-ventrally, with long and narrow, broadly rounded apex. Type: *P. facialis* Sm. Perkins ([6]) established the genus *Nesoprosopis* to unite 52 Hawaiian species; but after having found two of its species in Europe and China Meade Waldo ([5]) came to consider this genus as a subgenus only, which is really appear to be. The nesting habits of species vary; four species are parasitizing in nests of their nearest kin in the phylogenesis.

8. Subg. *Nesylaeus* Bridwell 1919. Judging from the description ([7]), the subgenus should be placed along with the subgenus *Nesoprosopis*. Type: *P. nesoprosopoides* Bridwell.

9. Subg. *Paraprosopis* nom. nov. (syn. *Asininus* division Metz 1911, *Campanularia* Mehely 1935 nec Lamarck 1816). Scent glands on sternite VI strongly developed. Basal and accessory apical lobes of sternite VII developed, usually broad and equal to one another, hairs and plates lacking. Sternite VIII broad with long triangular basal lobe, and mainly narrow and long, usually parallel-sided apical lobe, expanding at the broadly depressed and short-haired apex. Stipites quite broad and short at the base, and narrow and long at the apex clothed with plumose hairs. Sagittae slightly broadening dorso-ventrally, nearly parallel-sided and long and narrow apically. Type: *P. pictipes* Nyl.

10. Subg. *Nylaeus* (F.) (syn. *Cressoni* division Metz 1911; *Pectinata* Mehely 1935; *Trichota* Mehely 1935). Apical lobes of sternite VII strongly developed, triangular, bearing along the margin either a number of ridge-like plates, curved at the free end, or a number of large acicular setae; accessory lobes strongly elongated, tongue-shaped, usually narrow, covered with hair either completely or on the top. Sternite VIII short, with short and quite broad basal lobe, and usually long and narrow, short-haired strongly expanded and serrated apical lobe, in length usually equal to the body of the sternite. Stipites quite short and broad, broadening at the base; rounded apical half partly covered with feathered hairs. Sagittae broadening dorso-ventrally, with short rounded apex. Type: *P. annulata* L. Metz ([3]) identified 3 subgroups within the «*Cressoni* division» distinguished by minute structural details of the apical lobes of sternite VII; one subgroup (*P. tridentulus*) fully corresponds with the subgenus *Pectinata*, and the other (*P. varifrons*) with the subgenus *Trichota* Mehely.

11. Subg. *Deranchylaeus* Bridwell 1919. The analysis of the description, likewise of the genitalia with the adjoining sternites in a number of species leaves no doubt but that it is very close to, if not identical with the group *Trichota* Mehely. Should this assumption prove tenable, this subgenus is to be regarded as completely synonymous with subg. *Hylaeus*.

12. Subg. *Lambdopsis* Mehely 1935. Scent glands on sternite VI strongly developed. Apical lobes of sternite VII strongly reduced, chitinized, transversely rectangular with outer lateral margin inflated and directed backwards; no accessory lobes showing. Sternite VIII short and broad with narrow and long basal lobe, exceeding the length of the sternite body; apical lobe narrow, nearly equal in length to the basal one, ventrally hooked at the pointed and sparsely haired free end. Stipites broad and elongate with slightly tapering feather-haired apex, either rounded or angular. Sagittae short and broad with lobe-shaped broadened and sharply isolated angular distal half. Type: *P. annularis* K.

13. Subg. *Spatulariella* nom. nov. (syn. *Spatularia* Mehely 1935 nec W. van Deventer 1904). Scent glands on sternite VI underdeveloped. Apical lobes of sternite VII reduced, triangular, destitute of hairs and setae, basal lobes sometimes distinctly broadened. Sternite VIII short and broad; basal lobe narrow and apical lobe very long and very narrow; the former is equal to, the latter exceeds several times the length of the sternite body and is discoidally expanded at the free end. Stipites narrow and long with the apical feather-haired portion very much tapering and narrow, nearly rounded in the transverse section; strongly projecting beyond the apex of sagittae. Sagittae quite short and broad, with sharply isolated narrow and pointed apical half. Type: *P. hyalinata* Sm. A sharply isolated group, perhaps, to be classed as an independent genus.

14. Subg. *Hoploprosopis* Hedicke 1926. An analysis of the description leads to the suggestion that this subgenus may prove to be a synonym of the genus *Metylaeus* Bridwell 1919. To put this assumption to test, it is necessary to study the genitalia as in the case of subg. *Prosopisteron* Ckll. 1910 whose subgeneric assignment awaits confirmation.

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PALEONTOLOGY

SCIUROMORPHA AND *DIPODIDAE* (*GLIRES*, *MAMMALIA*) IN THE TERTIARY OF KAZAKHSTAN

By A. I. ARGYROPULO

(Communicated by A. A. Borissiak, Member of the Academy, 13. VII. 1939)

Our previous notes ([1], [2], [3]) contained brief data on the treatment of *Cricetidae* from the Oligocene of Kazakhstan. In the present communication are given the results of a study made on a rather scanty fossil material of *Sciuromorpha* and *Dipodidae* from the same region and horizon. Remains of *Dipodidae* are of unquestionable interest, being the most ancient find in Asia; besides, the specimens found seem to be representatives of highly organized groups of this family. In the USSR occurrence of *Sciuridae* and jerboas in Tertiary deposits has been reported for the first time.

Prosciurus sp. (? *lohiculus* Matth. et Granger)

Material. No. 1442/39 from the collection of the Paleontological Institute of the Academy of Sciences. A fragment of mandibulae sin. with P_4—M_2. Bone strongly mineralized («resonant») of light colouring, excellent preservation. Belonging to an old animal: molars strongly worn.

Horizon and Locality. Upper Oligocene (*Indricotherium* layers), Myn-sai, Central Kazakhstan (M. V. Boyarunas and M. G. Prokhorov, 1915).

The remains of a representative of *Sciuromorpha* here described are the second finding of the genus *Prosciurus* on the Eurasian continent. The first reliable information may be found in the article by Matthew and Granger([4]) who described *Pr. lohiculus* from the Oligocene of Mongolia (Hsanda Gol formation). To describe this species the authors had at their disposal teeth of the upper jaw; therefore, having molars of the lower jaw alone, we are unable to clear up the question as to what species the Kasakhstan *Prosciurus* belongs. If we are to judge from the analogy with species of genus *Cricetops*, we may believe this to be a closely related or even identical form. As to generic determination, we find the matter scarcely worth discussing, until more abundant new material is available. Wood ([5]) has arrived at a somewhat different conclusion; though referring the material from the Oligocene of Soskatchevan to *Prosciurus* aff. *lohiculus*, he states that «this form, together with the Mongolian one, may be sufficiently distinct to warrant generic separation from *Prosciurus*, when better known».

When comparing the material we dispose of with descriptions of numerous species of the American *Prosciurus*, we may point out the most striking distinc-

tion, namely, the strong development of the hypoconid resulting in a greater prominence of the postero-external angle of the crown of each molar than, for instance, in *Prosciurus relictus* Cope (Fig. 1). The mesostyle spur, as may be noticed even on the strongly worn molars of our specimen, is well developed. The protoconid has apparently no branch (spur) which seems to have been well developed, e. g., in *Prosciurus relictus* and some of the *Sciuravus*. The entoconid lies isolated on all teeth. Each molar has two roots. Length of PM_4—M_2 is 7. 1 mm, length of PM_4—M_3 is 9.3+mm (alveoli). Length measured upon the crowns (along the paracone-hypocone line): PM_4—3.6 mm, the same of M_2—3.9 mm. Length of P^3 M^2 (sup.) in *Pr. lohiculus* (according to figure) 6.95 mm. Length of diastema in the Myn-sai specimen 5.4 mm. Judging from the preserved alveolus, the incisor was larger than in the modern *Sciurus* (s. l.), extended farther backward and deviated less labialwards.

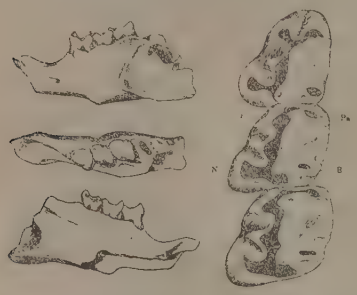

Fig. 1. *Prosciurus sp.* (? *lohiculus* Matth. et Gr.). Fragment of the left half of lower maxilla (viewed from outside, inside and from above) and P_4—M_2 (*Pa*—paraconid, *P* —protoconid, *E*—entoconid, *N*—hypoconid).

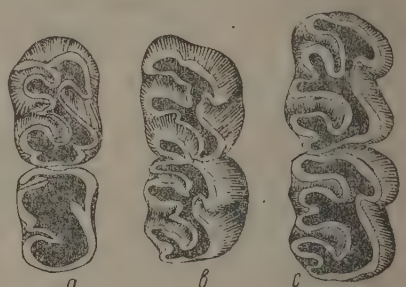

Fig. 2. M_1—M_2 (sup.): *a—Protaalactaga tunggurensis* Wood, *b—Protaalactaga borissiaki* sp. n., *c—Allactaga jaculus* Pall. (*b*, *c*—orig., *a*—after Wood).

There are many points still obscure in the classification of the numerous Paleogene representatives of *Sciuromorpha*. For instance, genus *Prosciurus* (isolated into a separated family *Paramyidae*) is referred by Miller and Gidley (6) to the superfamily *Dipodoidae*, thus being separated from *Sciuridae* (superfamily *Sciuroidae*, classification by the same authors). They assign to the superfamily *Dipodoidae* also *Pseudosciuridae*, the typical Paleogene *Sciuridae* of Europe, *Anomaluridae* and «*Idiuridae*». The North American Eocene *Sciuravus* is differentiated within the same superfamily and given the rank of a separate family *Sciuridae*. This classification seems to us rather artificial. *Prosciurus* stands obviously nearer to *Sciurus* (in the broad sense) than to *Castoridae*: the latter, however, are referred by the above authors to *Sciuridae*, while *Prosciurus* are classed among *Dipodoidae*.

The artificialness of Miller and Gidley's classification can be illustrated by a number of instances from other groups as well, such is, for example, the arbitrary separation of «*Graphiuridae*» from *Myoxidae* with the inclusion of African *Myoxidae* into the superfamily *Dipodoidae*, and of the Eurasian to *Muroidae*, etc. Simpson's classification (7) is obviously a happier one, since he places in the «infraorder» *Sciuromorpha* the families: *Aplodontidae*, *Sciuridae* (?=*Paramyidae*), *Heteromyidae*, *Geomyidae*, *Castoridae*, *Anomaluridae*, *Pedetidae*, *Ischyromyidae*, *Mylagaulidae*, *Chalicomyidae*, *Pseudosciuridae* and *Theridomyidae* (the last five are fossil). It is to be regretted that this system lacks adequate argumentation.

Protaalactaga borissiaki sp. n.

Material. No. 210/8. Fragment of maxilla dextra with a half of the bony palate, base of process. maxillaris arca zygom. and M^1—M^2. Bone strongly mineralized, of light colour, well preserved. Molars moderately worn.

Horizon and Locality. Upper Oligocene. Agyspe on the northern shore of the Perovsky bay, Aral Sea, Kazakhstan. Remains in green clay (J. A. Orlov, 1938). The same horizon has yielded the following rodents: *Schaubeumys aralensis* Arg. and *Sch. woodi* Arg., *Eumysodon spurius* Arg. and *Eum. orlovi* Arg., *Aralomys gigas* Arg. (*Cricetidae*), *Agispelagus simplex* Arg. (*Ochotonidae*), ? *Steneofiber* sp. sp. (*Castoridae*).

Diagnosis. Small rodent, tentatively assigned by us to *Protaalactaga* [the latter genus is very peculiar; it was described(9) as a representative of *Dipodidae*]. Length of M^1—M^2 4.8 mm. *PM* lacking. From the Miocene Mongolian *Pr. tunggurensis* Wood(8) it is distinguished by the absence of the premolar, shape of the crown of M^1, details in the pattern of the grinding surface and large size (M^1—M^2 in *Pr. tunggurensis*—2.54 mm). Structural differences from the Pontian North-Chinese *Pr. grabaui* Young(9) are vague, since the upper series of molars of the latter species is unknown. In size, our species is nearly equal to *Pr. grabaui*: M_1—M_2 (inf.) in the latter measuring 4.4 mm in length. There is hardly any reason to assume the identity of the new species with *Pr. grabaui*, the two being so remote from each other both in space and time.

Description. Crowns are more or less rounded, relatively brachiodont. The groove on the inner side of each molar while running somewhat obliquely forwards, descends but little below the middle of the height of the crown. Owing to the weak development of this groove, the inner margin of the crown is not divided into two lobate halves, which is so characteristic of representatives of *Paralactaga*, *Allactaga* and some other *Dipodidae* (Fig. 2, *c*). The outer side of the crown of M^1 shows two, and that of M^2 three rather deep grooves occupying half of the height of the crown. The anterior edge of the crown in M^1 is not regularly rounded, like in *Pr. tunggurensis*, but displays, probably on account of the strong development of anterior cingulum, a marked inward inclination as in *Allactaga*. The anterior external root of M^1 whose length exceeds time and a half the height of the crown, is set with a strong inclination forward and outward. M^1 measures 2.8 mm in length, 2.1 mm in breadth, M^2—2 mm and 1.7 mm respectively. Height of the crown (measuring from the surface of the maxilla) about 1 mm. Pattern of the grinding surface of the molars is partly still more simplified than in *Pr. tunggurensis*; the mesostyle spur is scarcely visible. M^1—metacone lying relatively isolated from the pseudopicone. The anterior cusp (cingulum anterior) is strongly developed (like in *Paralactaga* and *Allactaga*) and of a larger size than the protocone. The mesostyle heel appears in the form of a small protuberance. There is no posterior cingulum on this tooth. Judging from the figure given by Wood(8)*(Fig. 2, *a*) in *Pr. tunggurensis* posterior cingulum is well developed forming both a lingual and a labial branch. The structure of the elements in M^2 is essentially similar to that in M^1. The main difference lies in the development of posterior cingulum whose labial branch connects the metacone with the pseudopycone. Thus, the metacone does not occupy as isolated a position as in M^1. In general the second molar recalls much the one in *Allactaga* (for instance, *All. jaculus*); with mesostyle more strongly developed and groove on the lingual side of the crown elongated, this tooth in

* Wood's figure illustrates the difference in the amount of wear between M^1 and M^2.

Pr. borissiaki would become indistinguishable from corresponding molar in *Allactaga* (Fig. 2, *c*). As compared to M^2 in *Pr. tunggurensis* the species from Middle Asia has a very short mesostyle spur: in the former it reaches the edge of the crown. Finally, note should be taken that in *Pr. tunggurensis*, as compared to *Pr. borissiaki*, both M^1 and M^2 bear a very feebly developed anterior cingulum [«Vordercingulum» after Schaub(10)].

As regards the structural peculiarities of the fragment of the maxilla, the following may be stated. The posterior edge of the base of processus maxillaris is seen distinctly to turn aside already at the line between M^1 and M^2. A similar configuration of the upper maxillary process of the zygomatic arch (among the recent species of *Dipodidae*) we meet but in forms with weakly developed foramen infraorbitale (subfamily *Zapodinae*). The bony palate is very narrow: the breadth of its right half at the level of the midline of M^1 (measuring from the inner side of the alveolus) is but 1.3 mm. Thus, the total width of the palate in this region is but about 2.6 mm, slightly exceeding the breadth of M^1. Such a small breadth of the bony palate does not occur in modern *Dipodidae* (the bony palate attains its greatest breadth in representatives of *Zapodinae*, being comparatively narrow in *Allactaginae* and *Dipodidae*). The posterior edge of foramen incisiva lies about 0.6 mm away from the anterior edge of M^1.

The above diagnosis and description show the differences between *Pr. borissiaki* and *Pr. tunggurensis*. They are so important as to give rise to doubt whether this species has been correctly referred to the genus *Protaalactaga*. While fully sharing these doubts, we think the separation of a new genus on the basis of the scarce material on hand far-fetched, though the analysis of all the forms of Tertiary *Dipodidae* shows that, judging by the number of characters they have in common, the Middle Asiatic species should be placed between *Paralactaga* and *Protaalactaga*, somewhat nearer to the latter.

The relations between *Protaallactaga* and other fossil genera of *Dipodidae* appear to be as follows. In its general features, particularly in so far the pattern of the upper molars is concerned, *Protaalactaga* somewhat resembles the European Oligocene genus *Plesiosminthus* Viret. However, differences in the shape of the crowns, development of the mesostyle spur (causing no shifting of the paracone), elongation of the paracone and metacone, are rather essential in *Plesiosminthus*.

The East Asiatic genus *Heterosminthus Schaub* (11) is known but by its lower molars; their structure in *Heterosminthus* and *Protaalactaga* is suggestive of many sharp differences. *Protaalactaga* resembles still less the Pontian Mongolian *Sminthoides* Schlosser which show a rather simplified pattern of the upper molars, lacking, in particular, the mesostyle spur, with anterior cingulum practically undeveloped. As to «*Plesiodipus*» Young, the description of this rodent, as recently convincingly proved by S. Schaub(12), had been made after mixed remains of *Paralactaga* and *Protaalactaga*, whereas the teeth and fragments of the skull belong to a hamster-like rodent, subsequently given the name of *Plesiocricetodon*. The following two Asiatic genera—*Brachyscirtetes* Sch. and *Paralactaga* Young, stand nearest to the contemporary *Allactaginae*, as has been correctly pointed out by Vinogradow(13). These genera are characterized by an appreciable development of anterior cingulum, labial branch of superior cingulum, and by a peculiar expansion of the mesostyle spur on the upper molar, causing the paracone to deviate anteriorwards. As stated above, *Protaalactaga borissiaki* sp. n. has many characters similar to those in representatives of the above genera (Fig. 2). It seems to us that it may be regarded as the most ancient and partly the most primitive representative of the group of *Dipodidae* which is now included under the

subfamily *Allactaginae*. *Pr. tunggurensis* exhibits less likeness to representatives of this subfamily.

In concluding this review, we suggest the following scheme of distribution in time of all known Tertiary *Dipodidae* (table).

	Asia	Europe
Pliocene	1. *Heterosminthus* 2. *Brachyscirtetes* 3. 4. *Paralactaga* (*anderssoni*, *suni*) 5. *Sminthoides* 6. *Protaalactaga* (*grabaui*)	
Miocene	7. *Protaalactaga* (*tunggurensis*)	
Oligocene	8. *Protaalactaga?* (*borissiaki*)	9. *Plesiosminthus* (*myarion*) 9. *Plesiosminthus* (*myarion*) 10. 11. *Plesiosminthus* (*promyarion*, *schaubi*)

Note: The Pontian stage is referred to the Lower Pliocene. 1. Kansu (Ping-Fang-Hsien). 2. Mongolia (Ertemte). 3. Kansu (Ching-Chuan-Hsien). 4. Shensi (Shenmu). 5. Mongolia (Ertemte). 6. Kansu (Ping-Fang-Hsien). 7. Mongolia (Tung-gur). 8. Middle Asia (Aral Sea, Perovsky bay). 9. Chavroches, Paulhiac, Tomerdingen. 10. Puy de Montdoury, Rickenbach. 11. Branssat (Localities, according to numbers of animals in the scheme).

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